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BULLETIN 168 JUNE 1917

The University of Minnesota

AGRICULTURAL EXPERIMENT STATION

PRELIMINARY STUDY OF WHITE SPRUCE IN MINNESOTA

BY

W. H. KENETY

FOREST EXPERIMENT STATION, CLOQUET

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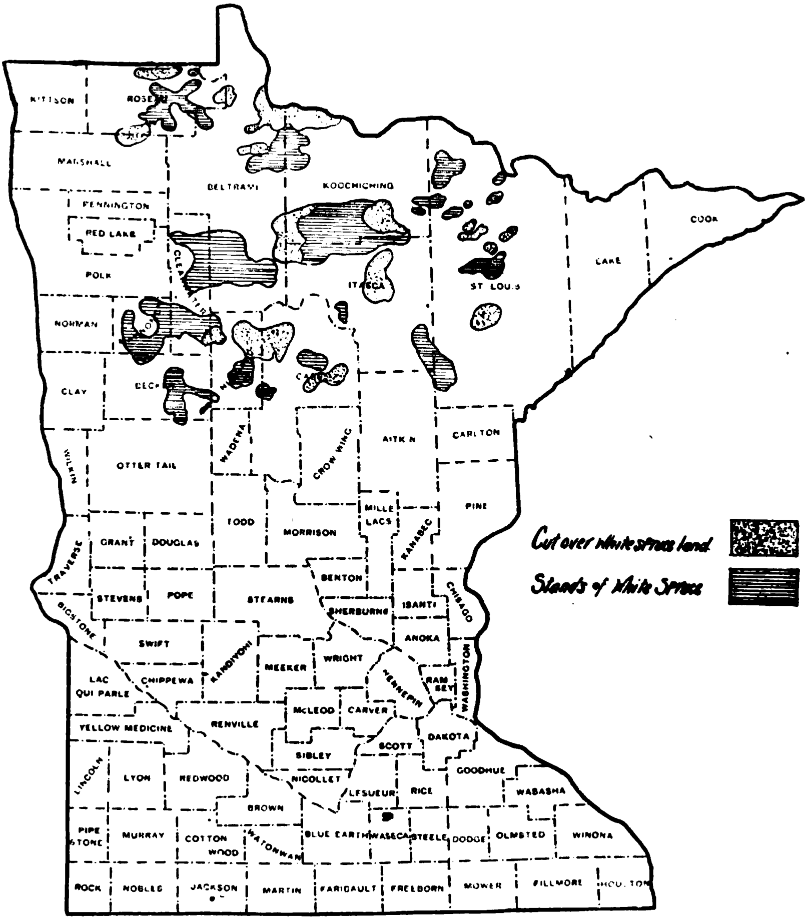


Fig. 1. Location of Best White Spruce Land

PRELIMINARY STUDY OF WHITE SPRUCE IN MINNESOTA

By W. H. Kenety

INTRODUCTION

The data obtained on growth, yield, and distribution of white spruce in the state have been assembled and the approximate returns which may be expected from young stands or plantations determined. Since little information on this species has been published it is thought that this study, tho not complete in itself, will be helpful to the state in its reforestation work, to the individuals who have land suited to spruce, or to corporations that may wish to grow a perpetual supply of spruce for industrial purposes.

The writer wishes to acknowledge the valuable assistance of G. H. Wiggin, A. F. Oppel, and K. J. Braden in collecting data, and of J. H. Allison who aided in the collection of data on volume studies and gave helpful suggestions on taxation principles.

Spruce constitutes approximately eighty-five per cent of the wood which goes into the manufacture of newspaper. Several species are used, the red spruce in the eastern states and the black and the white spruce in the Lake states. Of these, white spruce produces the best fiber and grows most rapidly.

The increasing scarcity of spruce for pulpwood and the attendant increase in the cost of paper make it imperative that the supply of pulpwood be perpetuated if the industries depending on this supply for their existence are to continue, and if the cost of paper is to be kept within reasonable bounds.

In the manufacture of paper, the two prime requisites are cheap wood for pulp, and water power. The means and the cost of obtaining the latter are very carefully studied and provided by the manufacturers, but the testimony of many of the leading lumbermen and paper men before a committee of representatives of Congress on paper and pulp investigations, in 1909, showed that very little information was available and that not enough study had been given to the economic source of pulpwood. An investment of several million dollars often depends upon this supply. The testimony of a large number of paper men and pulp companies who made a close canvass of conditions in connection with a federal inquiry into the paper industry in 1917, showed quite convincingly that the exhaustion of the supply of pulpwood is largely responsible for the present high price of paper.

Fully one fourth of the pulp and paper used in this country is imported, a large percentage from Canada. In 1908, Canada imposed extra duties on pulpwood in the eastern provinces. It is possible that other duties will be imposed, in order that Canada may prolong her supply of wood for her own mills.

The Laurentide Paper Company, one of the largest paper companies operating in the St. Lawrence Valley, has made a careful estimate of the pulp resources of that region and predicts that unless very vigorous efforts are made to protect pulpwood from fire and to restock cut-over lands, the supply in the St. Lawrence Valley will be exhausted within fifteen years.

The virgin spruce supply of Minnesota is being rapidly exhausted. This is partly because the paper mills in Wisconsin now obtain a large part of their pulpwood from Minnesota. The supply of spruce in Wisconsin was at one time thought sufficient to last the paper industries of that state for all time, but it is now nearly all cut. It will be only a short time until the mills of Minnesota will be unable to get pulpwood, unless measures are taken to protect the young growth and to reforest the land in Minnesota which is admirably adapted to the growing of white spruce.

David F. Houston, Secretary of Agriculture, in an article published March 17, 1917, suggested that the spruce in the western forests and Alaska be used to supply the needs of paper men and publishers. This might be a good plan for the western consumers and also for the eastern users after the war. With the return of normal shipping conditions, it might be possible to ship paper or pulp to the east coast region by way of the Panama Canal cheaply enough to make this scheme possible, but it would be prohibitive to the paper manufacturers and the publishers of the Middle West. The freight alone on pulp or paper from the western coast towns to the Twin Cities is $15 a ton in carload lots. The rate from Cloquet to the Twin Cities is $1.64 per ton in carload lots, and from International Falls, the farthest removed paper mill in the state, $2 per ton.

A cord of spruce pulpwood weighs 2¼ tons when green and from 1½ to 1¾ tons when dry; and as will be shown later, from 5 to 7 cords of spruce can be produced in Minnesota for the cost of freight alone on a single cord of wood in carload lots from Seattle. Hence shipping pulpwood from the western states to Minnesota mills would be out of the question.

Therefore the only means of getting an adequate supply of pulpwood for the Lake states seems to be (1) protecting the young growth, and (2) planting the cut-over spruce lands. In studying the advisability of planting or managing a spruce forest as a source of raw material for a pulp mill, the cost of transporting raw pulpwood for long distances and the loss from fire in inaccessible regions of virgin supply are items that should be carefully balanced against a perpetual supply of wood readily accessible and easily protected and handled, as it would be in a managed forest.

Box factories, crating mills, excelsior plants, chemical utilization plants, and the use of preservatives have now greatly increased the value of the fast growing woods such as popple, white pine, white birch, and balsam fir which grow in mixture with the white spruce. Much of the land suited to the growth of white spruce carries a fair stand of these heretofore worthless species which can now be used and made to pay for the introduction of the more valuable spruce. These new uses of quick maturing associate species, eliminating the long-time investment, the high price of stumpage, arising from the increasing scarcity of lumber in the Lake states, and the great reduction in fire risk through the state and private fire patrols, have so changed conditions that the deductions made ten years ago as to the advisability of reforestation and the suitability of certain species to forestation are no longer applicable. The advisability of using suitable lands, both private and state, for the growth of white spruce and its associate species is much greater than it was a decade ago.

WHITE SPRUCE *(Picea canadensis)*

White spruce, also known as cat or upland spruce, altho limited in its range to a cold climate, is a tree of wide distribution. It extends from Maine to the northwestern corner of Minnesota. It is found in the Black Hills and extends in scattered stands to Alaska and the Arctic Ocean. White spruce grows faster than the black spruce of our swamps, or the red spruce of the East, and, altho sometimes called upland spruce and confused with these species, it has several distinguishing characteristics. The young branches, especially when crushed, have a strong fetid odor. The young twigs and ends of the branches are smooth, while those of the black spruce are covered with a brownish fuzz. The cones of the white spruce are quite long and slender in comparison with those of the black spruce, which are short and round. The cones of the white spruce drop off each year after the seed have fallen out, while those of the black spruce, clustered in the top of the tree, sometimes remain for ten or fifteen years. The wood under the bark of the white spruce is a light color, while that of the black spruce is a brownish yellow. This means of identification is often used in a stand where no branches or cones are near. A small blaze on a tree will usually be sufficient to reveal the color.

The branches of the black spruce are short and clustered near the top while those of the white spruce are longer and scattered more openly along the stem, forming a long crown. The average woodsman can usually tell them apart by the bark and the difference in the general shape, but the two trees are often so similar that some of the differences given must be noted in order to distinguish the two species.

SOIL

White spruce is nearly always found on rich, moist soil—generally lake or river drift. Soil seems to be the determining factor in its growth. White spruce is found in many conditions of climate, but always on rich drift soil. It does not grow in swamps as does the black spruce. The term "upland spruce" is a misleading term, because in the northeastern part of the state stands of black spruce mixed with jack pine are often found on high, rocky cliffs.

CHARACTERISTICS OF WHITE SPRUCE SOIL

A large part of the forest region of Minnesota has been cut over and burned over. It is of glacial origin and contains many kinds of soil, some of which are suited to white spruce, while others are better suited to other species. Owing to the ravages of fire, it is very difficult to tell from the vegetation alone whether any particular land is suited to the growing of white spruce.

In order to classify the soil, some standard is necessary. The best standard for this purpose so far determined at the Cloquet station, is what is known technically as the "moisture equivalent" determination. Roughly speaking, this standard gives the amount of water in the soil available for tree growth.

Many foot samples of soil were taken to a depth of five feet on areas in widely separated regions in northern Minnesota, where white spruce made the best development. These soils were used as a standard for comparing cut-over and burned-over areas on which there was no white spruce, to determine whether they were suited to that species. If the moisture equivalent of the soil in any of these barren areas was found to be similar to those of areas with fine stands of spruce, they were classed as white spruce land. In fact, the correlation between the moisture equivalent and the rate of growth has been found sufficiently definite to warrant a rough estimate of the probable yields on the basis of this one factor.

Plots were selected in the best stands to be found in all of the representative spruce regions of the state. In each plot studied, from four to six foot samples of soil were taken to a depth of five feet. All the first foot samples in each plot were mixed together to obtain an average. The same was done with the second, third, fourth, and fifth foot samples respectively.

These samples were sent to the Division of Soils, of the Agricultural Experiment Station and the moisture equivalent of each sample was determined. The results of these determinations are given in Table I.

TABLE I

Moisture Equivalent Determinations of White Spruce Soil

Location	First foot	Second foot	Third foot	Fourth foot	Average
	Per cent	Per cent	Per cent	Per cent	Per cent
Warroad	16.5	14.2	12.6	10.7	13.5
Northome	23.5	24.5	25.5	22.0	23.9
Effie	35.8	37.8	34.7	32.7	35.3
Horse Lake......	17.0	11.1	*	*	...
Cook	36.9	48.0	43.4	36.9	41.3
Average.....	28.8	31.3	29.2	26.1	...

* Rock.

The average of a large number of samples of pine soil taken in the vicinity of Cloquet shows the big difference in this respect between the white spruce soils and the pine soils. Table II is based on the average samples in this vicinity.

TABLE II

Moisture Equivalent Determinations at Cloquet

Species	First foot	Second foot	Third foot	Fourth foot	Average
	Per cent	Per cent	Per cent	Per cent	Per cent
Jack pine........	7.9	4.7	2.6	2.0	4.3
Norway pine.....	9.1	5.2	3.6	2.9	5.2
White pine.......	14.3	6.7	5.6	3.4	7.5

From the above figures, it is clear that white spruce is naturally adapted to a soil which is comparatively heavy for at least four feet in depth. Pine, on the other hand, will live and grow in a much lighter soil, because its more extensive root system penetrates deeper and enables it to use the water located at lower levels.

Even in the young seedlings, the difference between the root systems of spruce and pine is quite marked.

Nobbe grew seedlings of pine and spruce in large glass vessels and measured the roots.[1] The results were as follows:

---

[1] Jost, Ludwig. Lectures on plant physiology, Gibson's translation, p. 27. pp. 564. 1907.

TABLE III

Comparison of Root Systems of Pine and Spruce

Species	Number of roots	Proportional value	Total length of roots	Proportional value
			Feet	
Pine	3,135	24	39.33	12
Spruce	253	2	6.37	2

As the young trees grew larger, the difference between the roots of the two species was more striking. Because of its more extensive root system, the pine makes much better use of the limited water supply in sandy soil, and will grow where the spruce will not.

DISTRIBUTION

White spruce is distributed in more or less scattered areas over nearly all of Northern Minnesota that is forested. There are 3,120,000 acres of land in Northern Minnesota on which white spruce is still standing or from which it has been cut. White spruce is being cut off very rapidly.

The map, Figure 1, shows the distribution of white spruce in Minnesota.

TYPES

White spruce is not found in pure stands. In fact, it is quite rare to find white spruce composing more than half of the stand in any region. It is generally found mixed with popple, balsam, or white

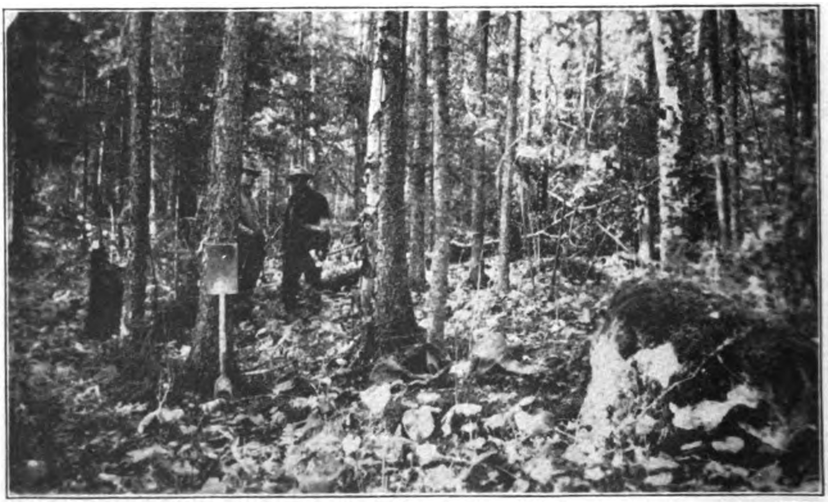


Fig. 2. Typical Stand of Black Spruce and Jack Pine With Occasional White Spruce, on High Moss-Covered Rock, Horse Lake

pine, and sometimes with all three. It also associates with balm of Gilead, tamarack, black spruce, cedar, and a few hardwoods, as birch and elm. The percentage of the different species obtained from sample areas in different parts of the state, is given in Table IV.

TABLE IV

Species in Acre Plots in Specified Localities

Species	Cook	Warroad	Northome		Effie	
Total number of trees	606	370	204	142	164	220
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
White spruce........	89	21	20	69	52	58
Balsam	4	9	40	12	6	..
Poplar	3	32	6	1	8	35
Tamarack	2	2	2	..	..	..
Black spruce........	2	2	..	4	4	3
Elm*	..	3	2	7	10	..
Balm of Gilead......	..	7	1	..	4	..
Green ash...........	..	24	1	..	4	..
Cedar	..	..	2	..	..	..
Oak*	..	..	2	..	..	..
Birch	..	..	2	4	12	..
White pine..........	..	..	2	1	..	1
Maple*	..	..	20	1	..	2
Jack pine...........	..	..	..	1	..	1

* Most of the elm, oak, and maple are very small and none reached a merchantable size.

AREAS STUDIED

While the vegetation generally associated with the well-stocked white spruce types of forest varies slightly on account of the different densities, it is generally uniform. The predominating species found in different parts of the state are as follows:

In the region of Horse Lake, Twp. 65 N., R. 11 W., Sec. 29, the whole country is rough and rocky with very little soil cover; in some places the soil has collected in pockets from one to three feet deep. (See Figures 2, 3, and 4.) In these pockets are found some popple and birch, the latter not very well developed. Dwarf maple and balsam comprise the underbrush. On the rocky hills and knolls black spruce and jack pine predominate. The soil in this type is very shallow and consists largely of broken rock covered with moss which holds enough water to keep the trees supplied. There is very little underbrush except scrub cedar and blueberry.

In the region of Warroad, Twp. 163 N., R. 37 W., Sec. 1, the soil is lake-washed till running somewhat to clay, with a heavy black

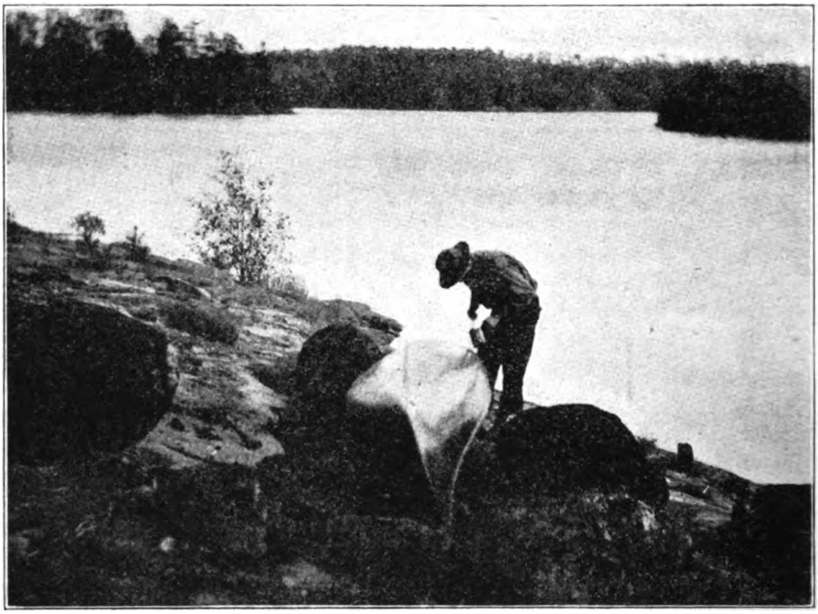


Fig. 3. Solid Rock Land on Which the Stand Shown in Figure 2 Grew

humus loam from six to ten inches deep on top. The predominating forest type is popple and white spruce, with some balsam and tamarack. The brush is small red maple, green ash, dogwood, alder, raspberry, and some scattered willow. The ground cover is moss, strawberry, partridge berry, goldenrod, Labrador tea, redtop, and bluejoint.

In the region of Northome, Twp. 151 N., R. 29 W., Sec. 25, the soil is a morainic land-laid clay. The clay is very heavy, with little humus cover and few rocks. The underbrush is quite thick and ranges up to ten feet in height. It is mostly maple, elder, and hazel. The ground cover is moss and there is very little herbaceous growth, mostly ground dogwood, honeysuckle, and grass.

In the region of Effie, Twp. 62 N., R. 26 W., Sec. 26, the soil is a very heavy morainic clay very much lacking in humus. The lower two feet are very calcareous. The underbrush consists of alder, green ash, and red maple, and the ground cover of moss, grass, and fern, some elm, and dwarf maple. The type here is mixed white pine, white spruce, and popple.

In the region of Cook, Twp. 62 N., R. 18 W., Sec. 17, the soil is heavy, laid-down clay with a good deal of lime and very little gravel within five feet or more of the surface, and with very little organic matter. The underbrush is medium thick except in open places and consists of maple, green ash, and some elder. Grass, mosses, and dwarf dogwood form the ground cover.

USES

The United States uses annually about three billion board feet of spruce of all species, for lumber and pulp.

The use of pulp wood for newspaper stock has increased since 1890. Between 1899 and 1909 the increase was about five per cent a year. Since 1915 it has been about sixty per cent. The recent investigations of the Federal Trade Commission show that 1,800,000 tons of newspaper were used last year. This means that about 2,700,000 cords of spruce were used for newspaper alone, estimating that about eighty-five per cent of the newspaper is made from spruce. Minnesota mills use annually about two hundred and fifty thousand cords of spruce for the manufacture of newspaper.

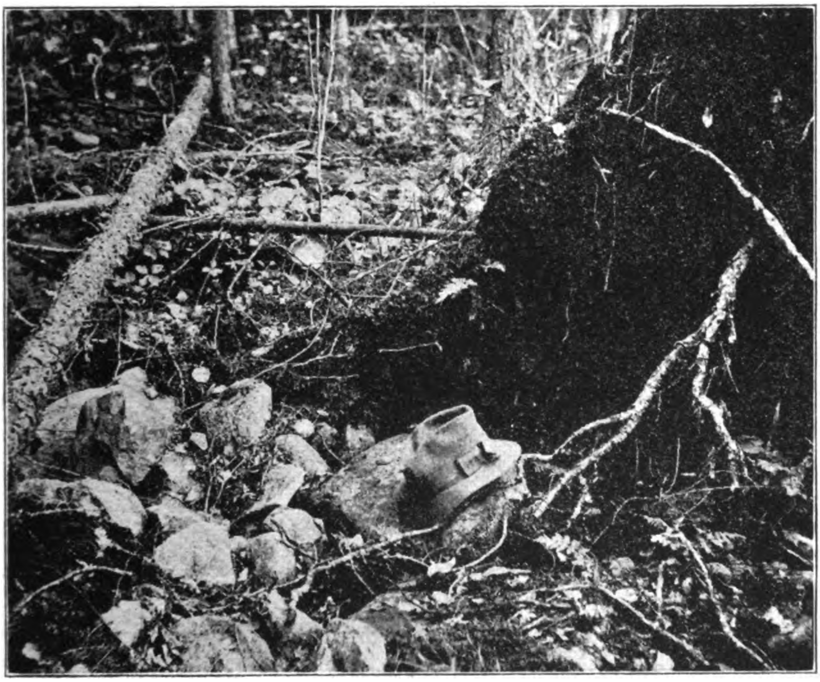


Fig. 4. White Spruce Uprooted
The rock subsoil is seldom more than two feet below the surface.

Spruce is used in the manufacture of many other products. About 7,250,000 board feet of spruce are used annually for veneer. Spruce is the wood most used in the manufacture of aeroplanes. The beams and frame work are nearly all spruce, either clear sticks or laminated strips glued and fastened together so that any weaknesses in one strip will not extend through the whole piece.

The percentages of spruce used for factory purposes are:

	Per cent		Per cent
Mill work	44	Woodenware and novelties	4
Boxes and crates	42	Tanks and silos	1
Musical instruments	4	Miscellaneous	5

The percentage of woods used in the structure of aeroplanes as given by Kellogg[2] is as follows:

	Per cent		Per cent
Spruce	63	Yellow poplar	6
Ash	16	Oak	5
Mahogany	8	Hickory	2

Spruce is also used for:

- Agricultural implements
- Aeroplanes
- Boats
- Oars
- Bowling alleys
- Boxes
- Broom handles
- Butter tubs
- Cable reels and spools
- Cameras
- Canoes
- Car sheathing
- Crates
- Doors
- Elevator platforms
- Fiber board
- Fixtures, backing and lining
- Fixtures, office
- Flat poles
- Flooring
- Furniture
- Guitars
- Hay presses
- Ice boxes
- Interior finish
- Key boards
- Ladder slides
- Mandolins
- Match cases
- Moldings
- Organ pipes
- Paddles
- Piano backs
- Piano sounding-boards
- Ships
- Shiplap
- Silos
- Sleds
- Spars
- Tables
- Tanks
- Tubs
- Vehicles

LENGTH OF FIBER

White spruce has a longer fiber than any of the other spruces. According to a Government bulletin,[3] the length of the fiber of the different spruces is as follows:

TABLE V

LENGTH OF WOOD FIBER

Species	Average	Maximum	Minimum
	Inches	Inches	Inches
White spruce	0.14	0.19	0.06
Red spruce	0.13	0.16	0.07
Black spruce	0.1	0.15	0.08

From this table it will be seen that, from the standpoint of length of fiber, white spruce is best for paper-making and probably allows the use of more balsam and other inferior, short-fibered woods.

---

[2] Kellogg, R. S. Lumber and its uses. pp. 352. pl. Radford Architectural Co., Chicago, 1914.

[3] Zon, Raphael. Balsam fir. p. 32, U. S. D. A. Bull. 55. pp. 68. 1914.

GROWTH

Sample plots averaging one acre in extent were selected in all of the regions studied. In most of the regions, three or four plots and sometimes five were measured. These plots were always located in the best stands because they most nearly represent the possibilities of the soil. Unfavorable conditions would be eliminated under management, and growth would be limited largely by the quality of the soil. Local forest rangers and residents were consulted in finding these stands, so that the plots may be said to be typical.

The region near Horse Lake, in Lake County, is typical of much of the country in northeastern Minnesota. According to the analyses (See Table I), the soil is considerably lighter than any of the other spruce soils studied. The ratio between the moisture equivalent of this soil and that of the average of the other soils studied was about one to two in the first foot and slightly less in the second one. As a consequence, this region, which according to meteorological records has as heavy a precipitation as any other part of the state, does not support white spruce so well as the heavier soils. The shallow soil, with its smaller water-holding capacity and permeable subsoil, which is usually broken rock, supports only those trees which are adapted to adverse conditions. White spruce in this region is found only in pockets where deeper soil and drainage provide an abundance of water. In this region Jack pine is usually mixed with spruce, and in most places composes the greater part of the stand. White spruce averages from six to eight trees, scaling not quite two cords to the acre. Typical trees in good locations reached a diameter, breast high, of twelve inches in about one hundred years, and an average height of 74 feet. Black spruce growing in the same plot was one hundred and two years old on the average, 7.1 inches in diameter, breast high, and 52.5 feet high. White spruce in this region reaches six inches on the stump, inside bark, in fifty years. Owing to the slow growth and to the nature of the topography and soil, it does not seem advisable to attempt artificial reforestation with white spruce in this region except in the favorable draws and pockets.

Near Cook the soil is a very heavy clay, averaging heavier than any other soil on which white spruce was found. The stands were denser than in any other region examined, but the growth, though very good, was not quite so rapid as that found in some other regions. An acre measured in a young stand contained 560 trees, 295 of which were more than three inches in diameter and averaged 5.1 inches in diameter, breast high. The age of this stand was twenty-eight years. It contains 11¾ cords of merchantable pulpwood, and at the present rate of growth should produce an average tree, ten inches in diameter breast high, in between fifty and sixty years, and a yield of approximately fifty cords of pulpwood per acre. It would pay to reforest state lands in this region with white spruce, as the returns in sixty years would be far above the investment and interest on the investment.

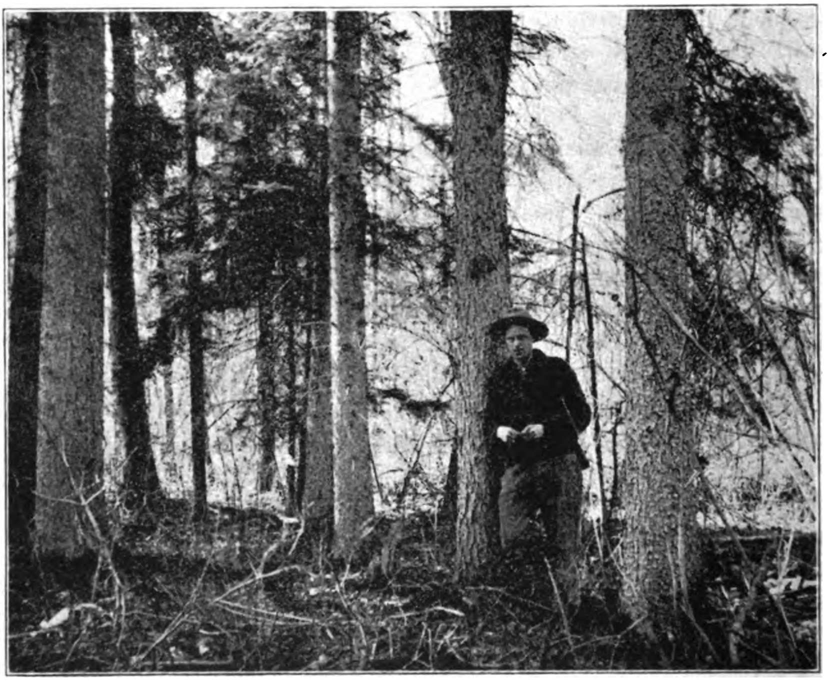


Fig. 5. White Spruce, Plot 4, Warroad

The soil near Warroad, as described elsewhere, is fairly heavy, tho it varies considerably. White spruce was more dense on the lighter soils in this region, the heavier soil being occupied more with balsam and popple, probably because the water table is very near the surface. The average of the soil samples showed that this soil was somewhat lighter than the average of the spruce soil for the whole northern part of the state, but owing to the high water table white spruce grows very well. The stand in which the sample plots were located was in excellent condition. The best sample acre measured contained 251 spruce trees, as well as a considerable amount of popple. The average height of the trees was 70 feet and the average age, ninety-three years; with an average diameter, breast high, of 10.03 inches. This stand compares favorably with yields of spruce in Germany on the best soil. (See Figure 5.) Under management, the Warroad soil should yield between 75 and 90 cords of pulpwood in ninety years, and should support a stand of 400 trees between ten and eleven inches in diameter, per acre. The best plot at present contains about 23,000 board feet to the acre, or about fifty cords of pulpwood. It would be profitable to plant all state land of this type to spruce. It would yield more than four per cent on the money invested. These deductions are made solely upon the present stand, and as these trees have been subjected to numerous fires and to natural enemies, it is safe to suppose that a much higher revenue could be derived from spruce forests on this land if properly cared for, and if all of the vacant spots were made to yield lumber. Thinnings would also produce pulpwood; and the revenue, accordingly, would be very much greater than that from the natural stands. This stand of spruce produced some trees six inches on the stump at thirty-five years and eight-inch trees at forty-five years. Allowing 850 trees to the acre, at thirty-five years the yield would be about thirty cords of wood per acre. With 750 trees to the acre, this land would yield five cords in thinnings at thirty-five years of age and approximately forty cords in a final cutting at fifty years.

In the region around Northome, the trees are of the very best quality and compare in rapidity of growth to the best growth recorded for acre stands in Germany. The average age of these trees was ninety years, the average diameter, 12.4 inches. The number per acre varied from 80 in one acre plot to 170 in another, and the ages were ninety

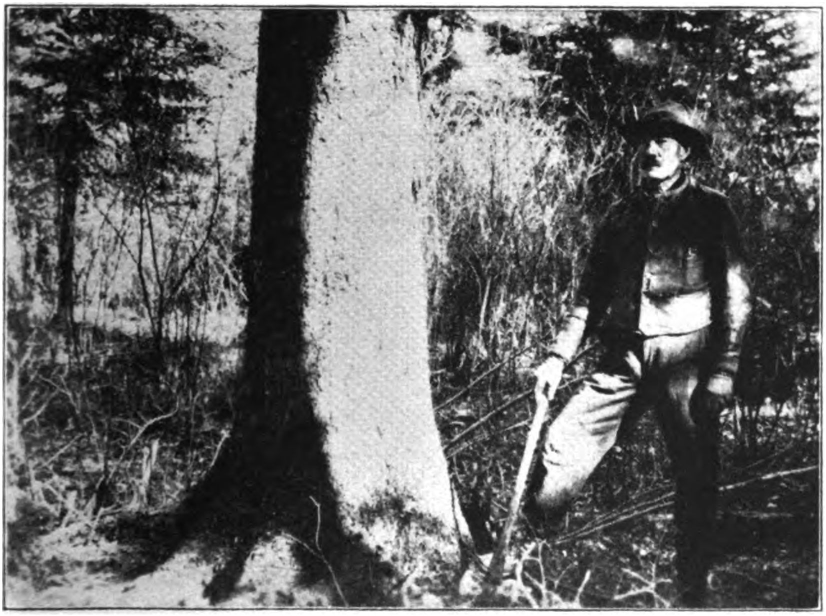


Fig. 6. Typical White Spruce More Than One Hundred Feet High, on Plot 2, at Northome

years in two plots, and ninety-two in the third. In ninety years this land would yield, under management, 100 cords of wood, or 50,000 board feet of lumber. It took this stand forty-six years to reach an average size of six inches in diameter. Some of the trees reached six inches in diameter in twenty-eight years. Judging from the average growth of the trees now on the ground, a fully stocked plantation on this soil, with 680 trees to the acre, would yield about fifty cords of merchantable pulpwood in forty-six years, including thinnings. (See Figure 6.) The soil at Northome seems to be particularly adapted to white spruce.

The soil in the region around Effie has been described in another part of this bulletin, and is quite similar to that found near Northome. The fastest growing spruce was found in soil which had a moisture equivalent of 28 per cent. One plot contained 52 trees to the acre, with an average diameter of 12.6 and an average age of one hundred and five years. Another plot on heavier soil, contained 126 trees which had an average diameter of 10.6 inches and were ninety-one years old. This plot at fifty years of age averaged 7.5 inches in diameter, and averaged 6.5 inches in forty years, altho many trees in the plot far exceeded these figures. For instance, one tree reached 10 inches in diameter in forty years and another 12.1 inches in fifty years. Some of the suppressed trees were 3.3 inches in diameter at fifty years, but these were in very crowded clumps. The growth in this region is about as good as any found in the state, but the density is not so great. It seems probable that this land, under good management, would yield as much as the best spruce land in Germany. For instance, 300 trees at the rate of growth shown by sample trees should yield from 80 to

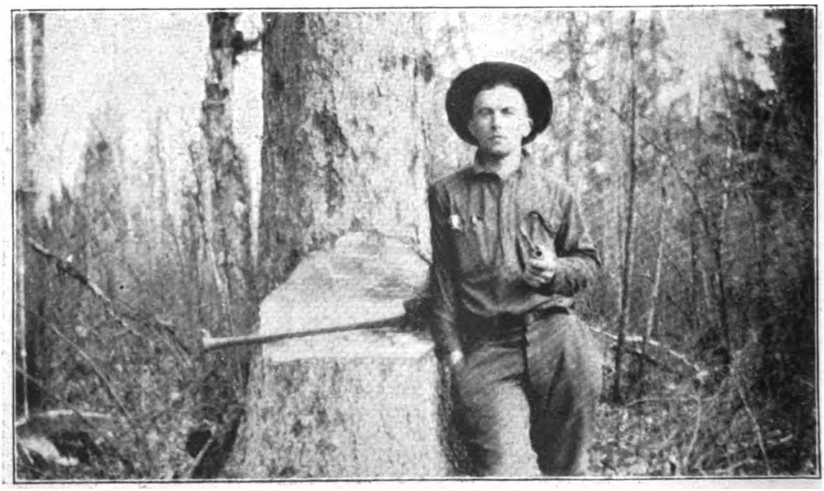


Fig. 7. Base of Tree 101 Feet High and 105 Years Old, at Effie

90 cords of wood at ninety years, while 700 trees to the acre at 6.5 inches diameter should yield 6 cords in thinnings and 45 cords at the end of forty years. This rate of growth would more than pay the cost of establishing spruce forests in this region and would yield a fine profit to the state. (See Figures 7 and 8.)

Tables VI and VII show the average growth in height and diameter of white spruce under good conditions in the different regions.

TABLE VI

GROWTH IN HEIGHT OF WHITE SPRUCE IN DIFFERENT REGIONS

Region	Years required to reach a height of	
	Thirty feet	Sixty feet
Horse Lake	33	90
Cook	26	..
Warroad	30	78
Northome	32	84
Effie	39	82
Kelliher	32	60

TABLE VII

GROWTH IN DIAMETER OF WHITE SPRUCE IN DIFFERENT REGIONS

Region	Years required to reach diameter breast high of					
	6 Inches		8 Inches		12 Inches	
	Average growth	Best growth	Average growth	Best growth	Average growth	Best growth
Horse Lake	50	45	65	59	100	90
Cook	35	30	..	..	..	..
Warroad	34	28	46	33	66	49
Northome	42	28	51	33	62	44
Effie	44	28	54	32	70	48
Kelliher	40	20	52	23	70	41

TABLE VIII

TOTAL YIELD ON ACRE PLOTS

Plot	Balsam		Spruce		Popple		Total	
	Cords	Bd. ft.	Cords	Bd. ft.	Cords	Bd. ft.	Cords	Bd. ft.
Cook—								
Plot 1	....	....	....	....	28	6,300	28	6,300
Plot 2	34	12,000	9	4,000	....	....	43	16,000
Plot 3	4½	....	11¾	....	....	....	16¼	....

TABLE VIII—*Continued*
TOTAL YIELD ON ACRE PLOTS

Plot	Balsam		Spruce		Popple		Total	
	Cords	Bd. ft.	Cords	Bd. ft.	Cords	Bd. ft.	Cords	Bd. ft.
Horse Lake—								
Plot 1........	....	....	1¼	800	10	4,000	11¼	4,800
Warroad—								
Plot 1........	....	....	....	....	27	8,500	27	8,500
Plot 2........	1	....	12¼	5,750	13	4,500	26¼	10,250
Plot 3........	12	Few	2½	1,100	13	4,300	27½	5,400
Plot 4........	....	....	52	23,000	....	....	52	23,000
Northome—								
Plot 1........	5	....	27	13,000	....	1,600	32	14,600
Plot 2........	¾	Few	42½	19,000	....	....	43¼	19,000
Effie—								
Plot 1........	14	....	15	7,000	8	4,000	37	11,000
Plot 2........	2	750	29	14,000	....	....	31	14,750
Plot 3........	....	....	....	....	43	17,000	43	17,000
Plot 4........	½	....	27	12,000	....	....	27½	12,000

TABLE IX
YIELD OF WHITE SPRUCE ON ACRE PLOTS

Region	Trees per acre	Average diam.*	Average height	Average age	Yield	
		Inches	Feet	Years	Cords	Bd. ft. M.
Horse Lake—Sec. 29, T. 65, R. 11...........	6 to 8	10-12	70.0	103	1¼	.....
Cook—Sec. 17, T. 62, R. 18, Plot 2.............	32	12.2	70.0	†	9	.....
Cook—Sec. 1, T. 62, R. 19, Plot 3............	563 295 over 3 in.	5.1	32.4	28	11¾	.....
Warroad—Sec. 1, T. 62 N., 37 W., Plot 2..........	38 over 4 in.	12.3	80.0	100	12¼	5¾
Warroad—Plot 3.........	8	12.4	75.0	†	2½	.....
Warroad—Plot 4	251	10.3	70.0	93	52	23
Northome—Sec. 25, T. 151, R. 29 W., Plot 1......	82 over 3 in.	12.4	85.0	90	27	13½
Northome—Sec. 19, T. 151 N., R. 28 W., Plot 2....	170	11.0	72.0	92	42½	19
Effie—Sec. 26, T. 62, R. 26 W., Plot 1...........	28 over 9 in.	15.7	87.0	106	15	7
Effie—Sec. 26, T. 62N, R. 26 W., N.E. ¼-N.E. ¼, Plot 2	82 over 3 in.	12.6	86.0	105	29	...
Effie—Sec. 21, T. 62, R. 25 N., S.W., S..E, Plot 4	126	10.6	74.0	91	30	13

* All measurements for diameter were taken 4½ feet above ground.

† In two of the plots which were on private land, permission could not be obtained to cut enough trees to learn the average age.

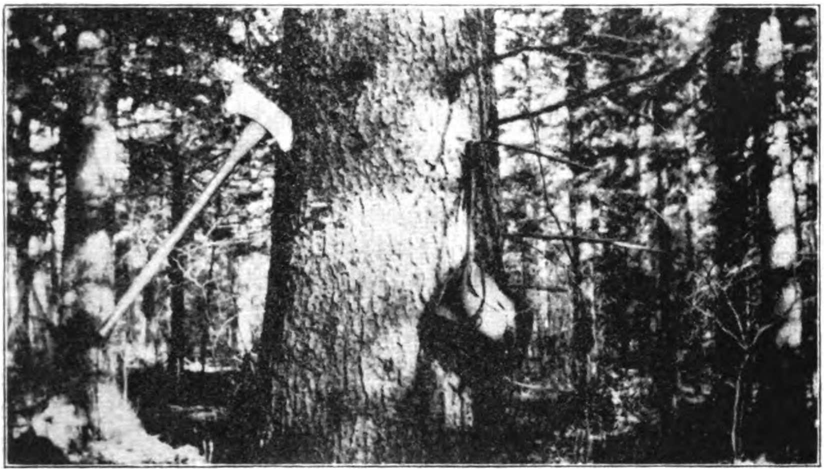


Fig. 8. White Spruce Nearly Three Feet in Diameter, on Plot 1, at Effie

VOLUME STUDIES

The greater part of the volume studies was conducted at a camp of the Crookston Lumber Company, near Kelliher, Beltrami County. The timber cut here averages twenty per cent white spruce and contains trees of all sizes, affording an exceptional opportunity for such a study. The soil is a light clay, well drained but moist, and ideal for the growth of white spruce. It is very much the same type of soil as that found in the Effie plots. Four hundred trees were measured.

All possible precautions were taken to insure accuracy. The calipers used were adjusted daily, and diameters were taken twice at each section wherever possible, in order to minimize the effect of irregularities in the trees. The measurements were taken as soon as possible after the trees were felled by the sawyers, before they were covered by other trees or debris. Starting at the stump, the stump height was taken, and its diameter inside and outside the bark, then the diameter at breast height, and after that the diameter outside the bark at each eight-foot section, beginning at the butt of the first log, and continuing to a diameter of three inches. The total height of each tree was measured and the thickness of the bark at the end of each eight-foot log. The age of the tree was obtained by counting the rings at the stump, and its rate of growth by measuring from the center, along an average radius, to every tenth ring.

The volume of each tree was figured in three different ways:

(1) By using measurements taken in the field, and the formula— V equals $L\ (\frac{B}{2}$ plus $B1$ plus $B2$ plus $B3$ plus $\frac{Bn}{2})$ in which L is the length of each section and $B1$, $B2$, etc., are the basal areas of each section.

(2) By using Schiffel's formula—V equals H (0.16B plus 0.66b) in which H is the total height of the tree, B is the basal area breast high, and b is the basal area at the middle point of the tree. The total volume of the 400 trees as obtained by Schiffel's method was one-half of one per cent greater than that obtained by measuring every eight feet. This shows that Schiffel's method may unhesitatingly be applied to white spruce with assurance of accurate results.

(3) By applying the Scribner rule and scaling each tree in eight-foot logs. From this computation was obtained a converting factor for changing cubic measure to board measure.

By computing the volume both outside and inside the bark, the percentage of bark was found to vary from 15 in the smaller trees to 10 in the larger ones. These figures may be of value to shippers of pulpwood, who may find it profitable to reduce their freight rates by peeling the pulpwood before shipment. The percentage of bark in different sized trees is shown in Table X and Figure 10.

Heights have been averaged and correlated with the age and diameter of the trees, to show what height to expect at a given age and to ascertain the taper at various diameters. The growth of trees in height will, of course, vary with the site, so that these figures could be applied to spruce only when growing on a similar site.

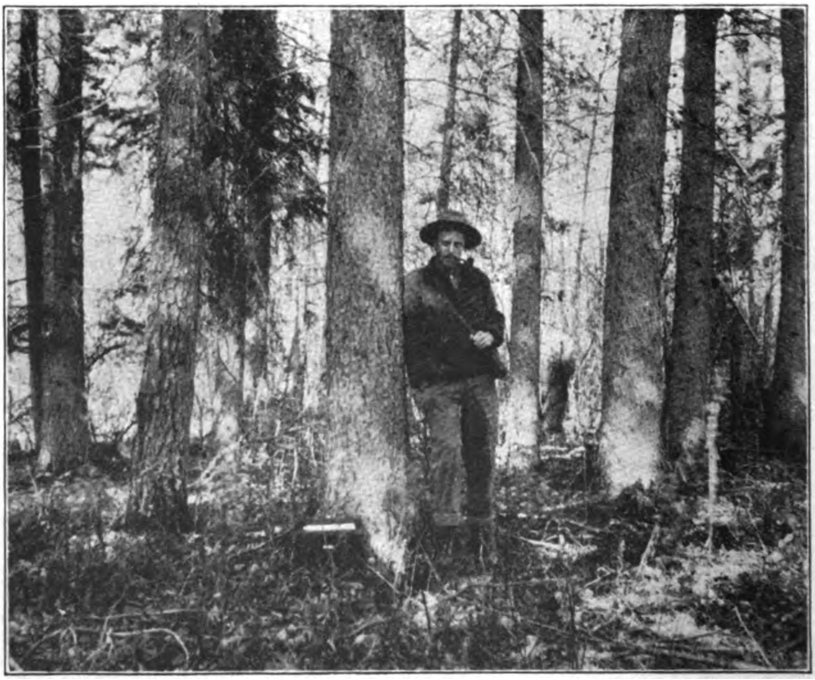
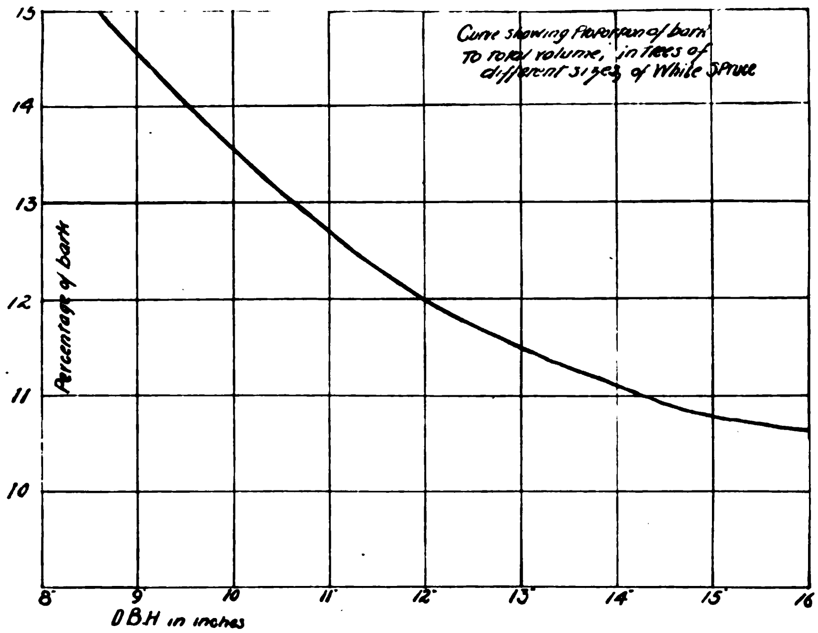


Fig. 9. Maximum Density of White Spruce at 100 Years of Age
The average is 251 trees, about twenty-three hundred board feet to the acre.



• Fig. 10. Percentage of Bark in Different Sized Trees

TABLE X

Percentage of Bark in Different Sized Trees*

Diameter Breast High Inches	Bark Per cent
8.5	15.1
10.7	12.7
12.7	11.8
16.1	10.6

* Based on the measurements of 400 trees at eight-foot intervals and the separate computation of the volume of each stick with bark and without bark.

The age and diameter of the trees have been tabulated in order to show the average height and diameter at any given age, and also to show how long it would take under similar conditions to produce trees of any given size.

The taper inside of the bark of an average white spruce in the stand at Kelliher is best shown by the taper curve based on the diameter, breast high, inside the bark, Figure 11 and Table XI.

Five hundred feet, board measure, to a cord is the common figure used in converting board feet to cords, and 96 cubic feet to a cord in converting cubic feet to cords.

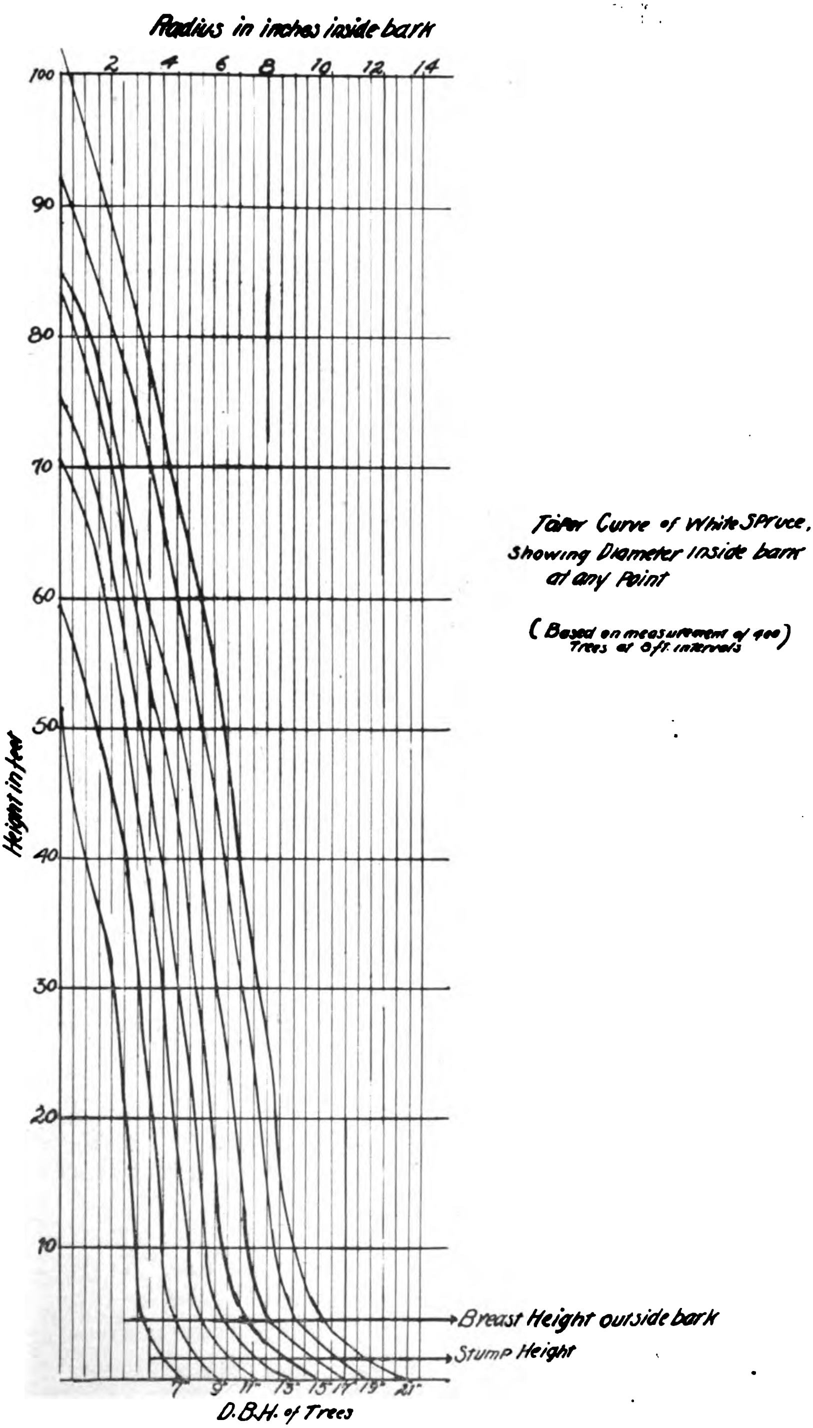


Fig. 11. Taper Curve of White Spruce

TABLE XI

Taper of White Spruce Inside Bark, Based on 400 Trees

Diameter breast high	Height stump	Stump D. I. B.	Total height	Diameter inside bark at eight-foot intervals										
				8	16	24	32	40	48	56	64	72	80	88
Inches	In.	In.	Ft.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
7	16.0	7.8	7.8	6.1	5.4	4.7	3.6	1.5	....	...	...	...	...	...
8	15.7	9.1	54.7	6.8	6.1	5.3	4.3	3.2	1.5	...	...	...	...	...
9	16.0	10.4	59.2	7.8	7.1	6.3	5.3	4.0	2.9	1.1	...	...	...	...
10	16.0	12.0	63.7	8.7	8.0	7.2	6.3	5.2	3.8	2.2	...	...	...	...
11	17.0	13.0	70.7	9.7	8.9	8.1	7.2	6.2	5.2	4.3	2.0	...	...	...
12	17.7	14.1	72.8	10.4	9.6	8.8	7.9	6.9	5.7	4.2	2.5	...	...	...
13	19.3	15.4	75.1	11.3	10.5	9.6	8.7	7.5	6.5	5.1	3.4	...	...	...
14	19.8	16.4	82.2	12.1	11.3	10.8	9.6	8.5	7.4	6.1	4.6	3.1	...	...
15	19.5	17.8	83.8	12.8	11.9	11.0	10.1	9.0	7.6	5.8	4.9	3.1	...	...
16	20.5	18.7	82.2	13.8	12.8	11.9	10.9	9.7	8.1	6.8	5.2	3.7	1.2	...
17	20.4	20.1	84.7	14.5	13.4	12.5	11.6	10.3	9.1	7.4	5.6	4.0	1.6	...
18	19.5	21.3	89.7	15.6	14.8	14.0	12.8	11.6	10.4	9.1	7.1	5.4	3.1	...
19	21.4	21.7	91.6	16.8	15.5	14.6	13.4	12.4	11.1	9.6	8.0	6.2	3.8	1.9
20*	....	....	....	....	....	....	....	....	....	....	...	...	...	...
21	20.3	23.8	101.9	18.1	16.9	16.1	14.9	13.9	12.8	11.3	9.8	7.7	5.9	3.3

* Not enough trees to insure a dependable average.

No constant factor can be used, however, because the factor varies with the size, taper, straightness, and soundness of the logs measured. It is obvious that a stand of spruce might be composed of six- or seven-inch trees and contain a large number of cords and cubic feet, and yet scale and saw out very little merchantable lumber, while a stand composed of a smaller number of trees with an average diameter of 12 inches might contain the same number of cords and cubic feet, and yet yield a much larger amount of merchantable lumber.

Table XII and Figure 12, based on the measurement of 400 white spruce trees, show the ratio of board feet to cubic feet in trees between 7 and 20 inches in diameter, breast high.

TABLE XII

AVERAGE NUMBER OF BOARD FEET TO EACH CUBIC FOOT, BASED ON DIAMETER BREAST HIGH, OUTSIDE BARK

Diameter breast high	Average height	Board feet to one cubic foot
Inches	Feet	
7	50	1.4
8	55	2.4
9	60	4.3
10	65	4.8
11	70	5.2
12	72	5.4
13	75	5.5
14	78	5.6
15	80	5.7
16	82	5.9
17	85	6.0
18	90	6.2
19	95	6.3
20	100	6.4

TABLE XIII

RELATION BETWEEN DIAMETER OF STICK AND VOLUME OF WOOD*

	Pieces measured	Eight-foot sticks per cord	Average diameter, inches	Cubic feet per cord
Pile 1..................	663	66.3	5.76	96.01
Pile 2..................	592	70.0	5.60	95.68
Pile 3..................	778	73.0	5.42	93.68

* The sticks measured ranged from three to eighteen inches in diameter.

TABLE XIV

VOLUME AND HEIGHT AS RELATED TO DIAMETER, BREAST HIGH, INSIDE BARK IN NATURAL MIXED STANDS

Diameter breast high (Inside bark)	Height	Volume		
		Inside bark		Including bark*
Inches	Feet	Cu. Feet	Bd. Feet	Cords
7	51.6	6.53	9.2	0.06
8	54.6	8.11	19.5	0.073
9	59.3	11.10	48.4	0.1
10	63.2	14.75	71.3	0.12
11	70.1	18.93	100.6	0.17
12	72.3	23.70	123.2	0.21
13	74.2	28.34	160.0	0.25
14	82.7	34.28	190.0	0.3
15	83.0	39.21	226.2	0.34
16	83.2	44.96	269.3	0.4
17	84.5	52.72	246.3	0.45
18	89.7	64.24	407.3	0.53
19	91.1	70.58	497.5	0.6
20	101.0	88.41	542.5	0.75
21	102.5	94.07	612.5	0.81

* Taken to four-inch top.

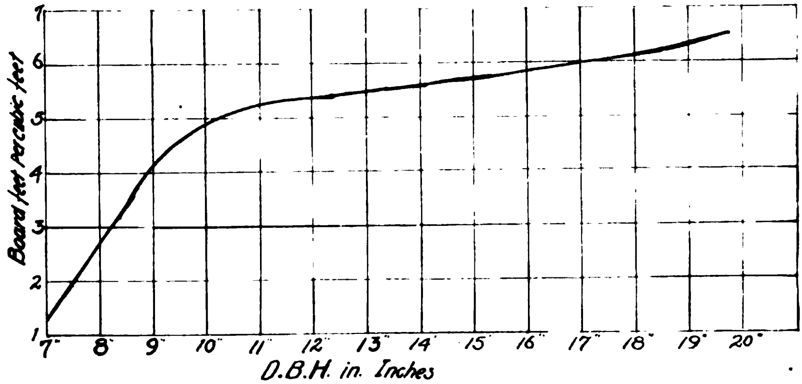
These figures are based on measurement and individual computation of 400 trees in a white pine-white spruce stand with a mixture of some hardwoods. The stand was typical of the spruce type in the region of Red Lake. Many of the trees have been suppressed at one time in their development.

TABLE XV

VOLUME INSIDE BARK OF DOMINANT TREES BASED ON AGE AND THREE-INCH TOP*

Age	D. B. H.	Height	Volume		
Years	Inches	Feet	Cu. Feet	Cords	Bd. Feet
10	1.0	8	...	...	...
20	3.0	20	0.38	...	...
30	5.6	35	2.4	0.02	10
40	8.4	50	7.5	0.08	30
50	10.9	65	14.6	0.15	80
60	12.9	75	25.1	0.27	135
70	14.9	85	39.4	0.42	225
80	16.9	90	56.6	0.61	320
90	18.7	95	72.5	0.7	450
100	20.6	100	92.6	0.93	590

* This table is based on the dominant trees in the Kelliher region and shows the results to be expected from plantations on this type of soil.



Curve for converting cubic feet to board feet
in
White Spruce

Fig. 12. Ratio of Board Feet to Cubic Feet in White Spruce

POSSIBILITIES OF PRIVATE INVESTMENTS

The pulp and paper mills of Minnesota represent a very large investment. Their immediate source of raw material is mostly the spruce growth of the swamps. In a very short time it will be hard for most of the mills to obtain raw material within a reasonable distance. The increased cost of transportation as the supply is pushed back farther and farther, together with the growing scarcity of the supply, will necessarily increase the cost of the raw material at the mill as it already has in New England, New York, and Wisconsin. For instance, the price of peeled pulpwood at the mill in New York averaged $14 per cord two years ago, an advance of about thirty per cent over the price of four years ago. Owing to the war, this price has increased to $24. In Wisconsin it is reported to have reached $25 per cord, f.c.b. mill.

This brings up the question of whether it would not be a paying investment for mill owners to establish, near the mill, plantations of spruce that would furnish indefinitely an adequate supply of raw material. The data in this report indicate that this is feasible. The investment would not be so large as would be necessary now to buy and hold a supply as great as could be raised on a perpetual basis. Moreover, the ultimate exhaustion of any supply bought at the present time, no matter how large, is certain unless some measure is taken to perpetuate it.

What investment would be necessary to establish a plantation large enough to supply a mill using 25,000 cords of pulpwood annually, the first cut other than thinnings to be made in fifty years?

The data collected show that fifty cords per acre is a probable yield at the end of fifty years on the proper type of soil. The cut from 500 acres would be required to supply the raw material for a year. Therefore, 25,000 acres must be planted if a series is to be established that will supply the mill indefinitely.

This would entail the cutting of 500 acres and the planting of 500 acres after the first cut. In the start, it would be advisable to plant the tract in the first twenty-five years, if it were all purchased at one time.

It would probably be impossible to purchase 500 acres each year contiguous to the land previously purchased, so it would be necessary to purchase all or a greater part of the 25,000 acres at the start. This is a little over a township, and when bought in such a large quantity, should not cost over $5 per acre at the present time, deducting the value of the timber and young growth generally found on such land.

The cost of raising a cord of pulp wood on a fifty-five year rotation, figuring fifty cords to the acre at the end of fifty years, would be $2.25 per cord, allowing $5 per acre for the cost of the land and $7.50 per acre for the cost of planting, compounding the cost of land and planting at four per cent annually for fifty years. This presupposes that all the 25,000 acres were bought at one time and planted during the first twenty-five years.

Taxes and administration computed at 10 cents per acre per annum compounded at four per cent would amount to 31 cents per cord based on a yield of fifty cords to the acre at fifty years.

Taxes, of course, vary greatly in different regions, but the same ratio would hold true. For instance, with an annual tax of 20 cents per acre per year, under the same conditions, the cost of taxes would be 62 cents per cord.

It is estimated that thinnings on this fifty-year rotation would amount to eight or ten cords per acre without decreasing the final yield. These thinnings would to a considerable extent offset the cost of protection and taxes.

TAXING FOREST LANDS

The present system of taxation, if properly carried out, is unfair to the timber grower, because it provides for the repeated collection of taxes from the same crop, a condition which is not true in its application to the grower of farm crops. In farming operations, the crop is removed each year from the land which produces it, while in forest operations each year's crop must be stored on the ground until its accumulation in volume in the form of individual trees becomes sufficiently large to make it worth while to remove it. In reality, this year's forest crop (the growth which takes place this year within the forest) may have to be held from one to fifty years before it can be removed from the land. According to our present system of taxation, it is retaxed each year during this period. If the same land had been devoted to the production of farm crops, each crop would have been removed during the year in which it was produced and hence would have been taxed only once.

How may the unfairness of the present system to the timber producer be corrected without injury to the interests of the general public? By the retention of the present system of taxation as far as the land itself is concerned, applying the present general property tax to the sale value of the unimproved cut-over land only, and the substitution of a yield tax on the stumpage value of the timber just before cutting, in place of the present system of annually repeating the tax on the same forest crop.

The unfairness of the present system of taxation as applied to the productive forest has already been recognized by several states—Connecticut, Massachusetts, New York, Pennsylvania, and Vermont—which have passed during the last six years forest taxation laws, putting in force the practical application of the principles just brought out. Perhaps the most carefully worked out of these special forest taxation laws is the one passed in 1914 by the Massachusetts legislature, after it had been empowered to act by a constitutional amendment. The salient provisions of this law are:

1. The land to which the law is applied must be registered with the State Forester and State Tax Commissioner, thus making the application of the law to any particular tract optional with the land owner.

2. The land so registered must be stocked either naturally or from planting with commercial trees within a limited period of time after registration.

3. The assessment of the land at the proper proportion of its sale value as unimproved untimbered land and the annual payment of the general property tax on this assessment.

4. The substitution of a six per cent yield tax, based on a fifty-year rotation in place of the present annually repeated tax, on the value of the merchantable timber.

A forest taxation law of this kind probably does not subject the timber producer to any greater hardship than the farm crop producer, and at the same time enables him to compute quite accurately the total cost of taxation; while the present system, if actually enforced, may leave nothing for the timber producer after the taxes are paid.

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REPORT OF CLOQUET FOREST EXPERIMENT STATION

BY

W. H. KENETY

SUPERINTENDENT

UNIVERSITY FARM, ST. PAUL

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THE CLOQUET FOREST EXPERIMENT STATION

By W. H. Kenety

HISTORY

The conception of the Cloquet Forest Experiment Station and the arousing of the interest of the lumbermen that made it possible belong to the late Samuel B. Green. The Station was established in 1909 with D. P. Tierney in charge. Mr. Tierney resigned in 1911 and S. B. Detwiler was in charge for a short time. Following Mr. Detwiler's resignation in August, Walter McDonald, of Cloquet, was appointed temporary foreman. Since 1912, the author has been in charge.

The Station contains 2,640 acres, of which 2,240 acres were donated to the University by the officers of the logging interests centered at Cloquet. All the jack pine and all timber other than pine that was standing on the land at the time was also donated. The rest of the land was acquired by the purchase of certain Indian allotments that were within the tract.

A coöperative agreement was entered into with the United States Forest Service in 1912, and arrangements were made whereby the Station would serve both the state and the National forests in the Great Lakes region. Raphael Zon, of the United States Forest Service, aided greatly in formulating the plans for the investigative work.

This bulletin is not intended as a scientific publication, but a report of progress made in the sub-projects and a description of the methods used and the results obtained.

Summary tables have been included to aid other workers in comparing their results in simliar work.

ADMINISTRATIVE WORK AND IMPROVEMENTS

When the station was established, there were no buildings on the place, no roads, and no firebreaks. Their construction constituted most of the work of the first year and has been continued from time to time. There are now two residences, one for the superintendent and one for the foreman, who boards the hired men. Both of these buildings were constructed from logs cut on the Station land. An office, bunkhouse, and barn have also been built. These buildings are all in good condition with the exception of the barn. As it was made of old lumber, a new one will probably have to be built in a few years.

It is hoped that electrical connections will soon be made with Cloquet. This might prevent fire loss resulting from the use of matches, kerosene lamps, and lanterns. The risk is especially great in the case of the barn.

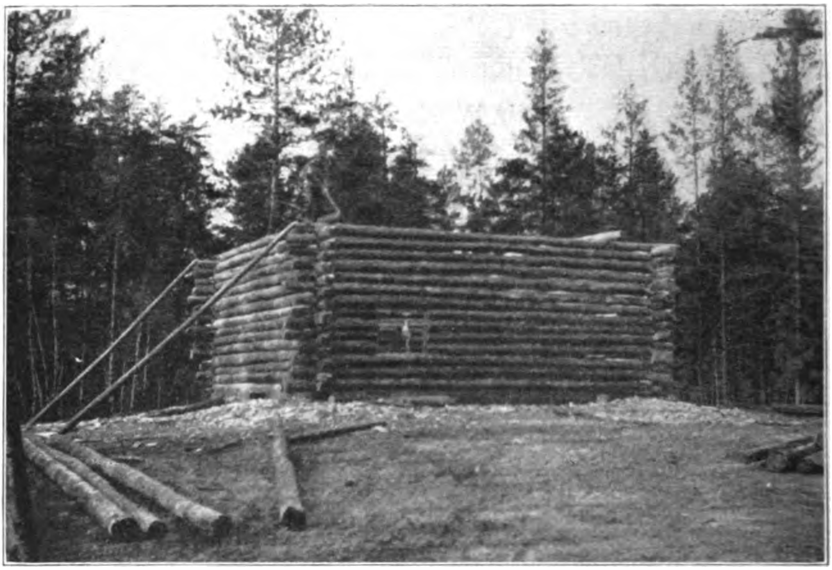

Fig. 1. Jack Pine Log Frame of Superintendent's House

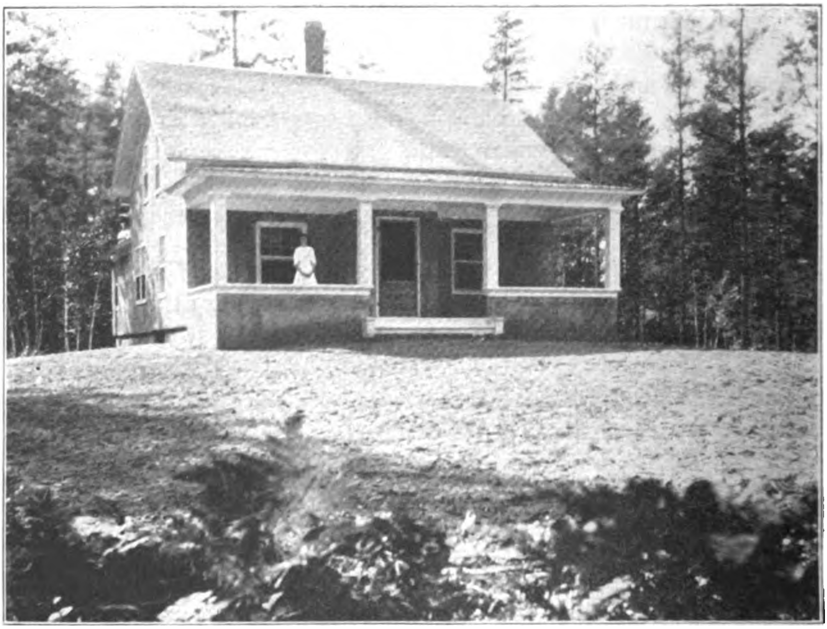

Fig. 2. Superintendent's House Completed

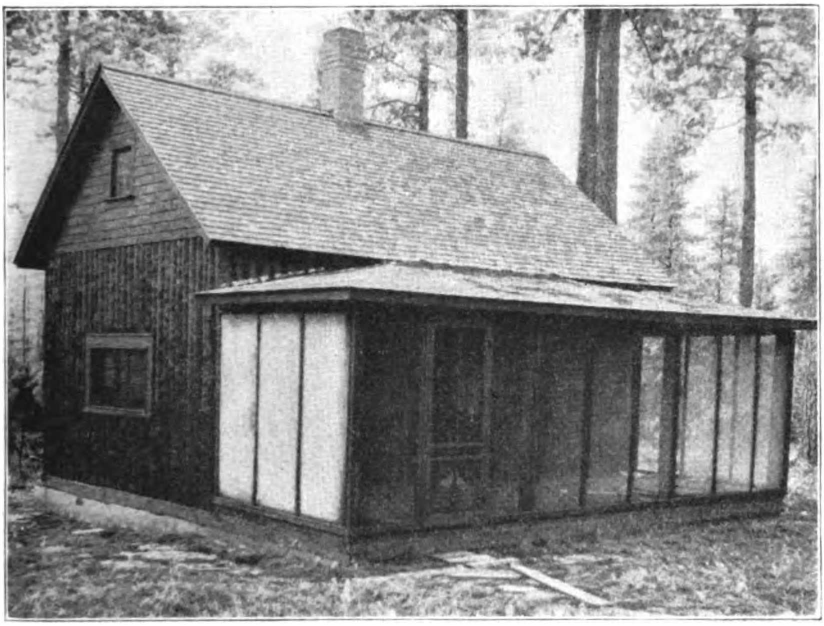

Fig. 3. The Bunkhouse; Men's Quarters

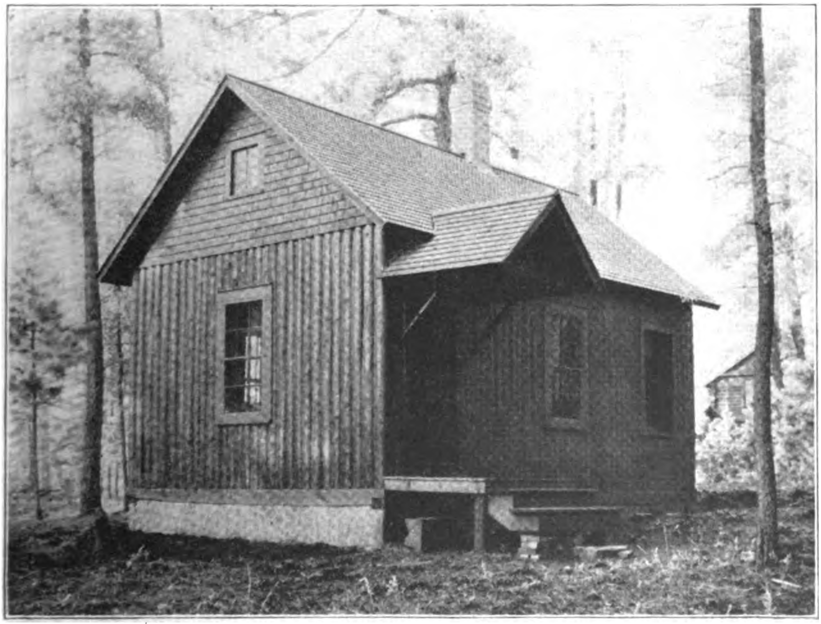

Fig. 4. The Office

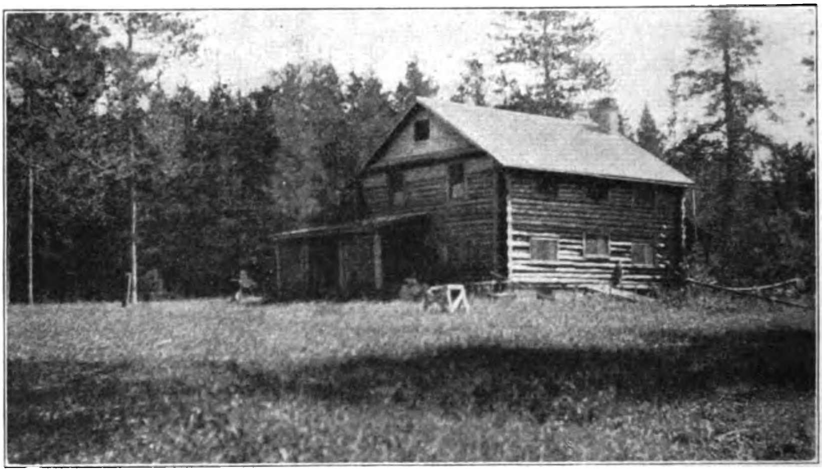

Fig. 5. The Lodge
The foreman's headquarters, where the men are boarded.

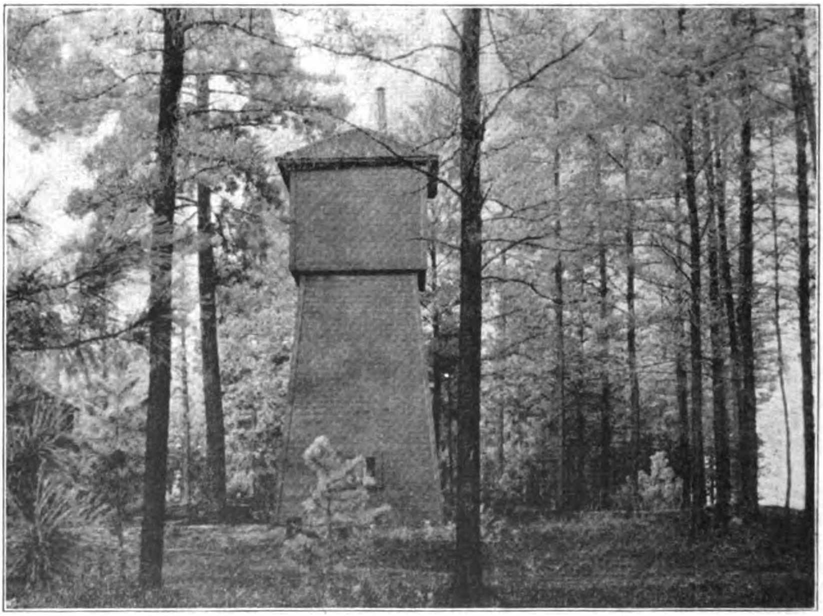

Fig. 6. The Tank House
This supplies water for buildings and nursery.

FOREST TYPES AT CLOQUET

The Station has about one and a quarter million feet of white and Norway pine in seed trees and scattered timber; a considerable amount of jack pine, spruce, balsam, and tamarack; and some cedar, birch, and poplar. There are hundreds of acres of burned-over and cut-over land and a large area of muskeg.

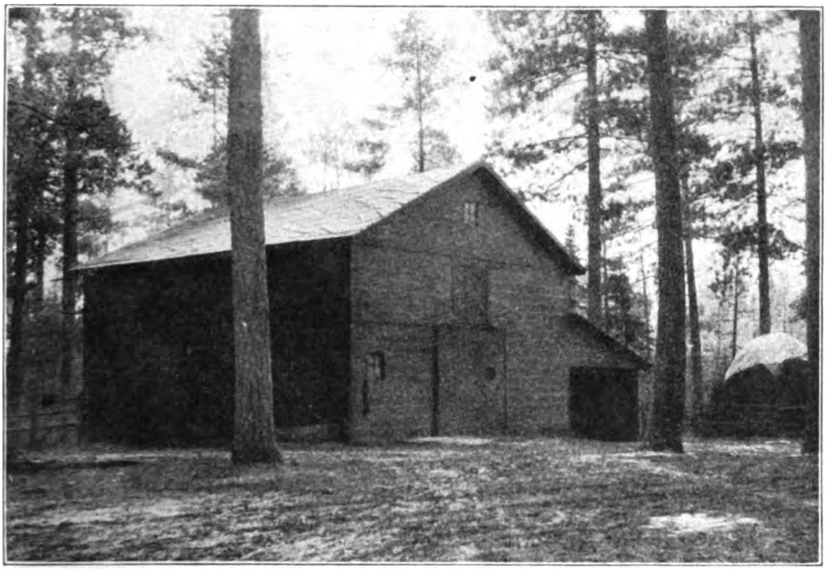

Fig. 7. The Barn

In order to carry on both experimental and constructive work, it was necessary to obtain definite information as to the location and acreage of these different types. The whole Station has been carefully surveyed and a map made showing the exact distribution of the different types; and a complete description of the soil, reproduction, undergrowth, and timber is on file. The acreage of the different types is as follows:

	Acres		Acres
Muskeg	198.6	Jack	528.4
Tamarack	533.4	Norway	85.0
Meadow	66.7	Norway and white	21.2
Spruce	27.9	Norway and jack	84.8
Hardwood	57.6	Nursery	10.9
Brush	607.6		
Jack and brush	417.9	Total	2,640.0

INVESTIGATIVE WORK

The investigative work at the Cloquet Experiment Station may be grouped under the following projects:

1. *Forestation*
    - a. General studies
    - b. Seed-production, viability, and methods of extraction
    - c. Nursery practice
    - d. Species, methods, and seasons for artificial reforestation

   - e. Sites—ecological conditions limiting the growth and development of each species
   - f. Exotics
   - g. Species not native to this region but climatically adapted

2. *Forest influences*
3. *Management*
   - a. Cutting systems for securing reproduction
   - b. Methods of cutting
   - c. Natural reproduction
   - d. Thinnings
   - e. Valuation—based on immature growth, soil suitable for forests, and other considerations
4. *Mensuration*
   Growth and yield of different species
5. *Sylvicultural studies*
   - a. Distribution of forest trees and types in the Lake region
   - b. Forest types—description and basis of determinations
   - c. Special studies
6. *Tree studies*
   Growth, yield, and methods of management of individual species

FORESTATION

Under Forestation is included the whole subject of growing trees from seed. This covers the collection of seed and its extraction and storage; all nursery experiments, such as time of sowing, depth of sowing, production, disinfection, amount of shade, methods of transplanting, and fertilizers; and all planting experiments, such as best age of stock, classes of stock, methods, trees adapted to certain situations, and exotics. These will be taken up in order.

Studies of the best methods of collecting, extracting, cleaning, and storing seed are considered under the heading Seed. Thousands of bushels of cones are shipped out of Minnesota every year, the seed from which are used in reforestation work.

In order to determine the cheapest and best methods of collecting, extracting, cleaning, and storing compatible with the highest quality of seed, studies have been conducted with white pine, jack pine, Norway pine, white spruce, and balsam.

Seed-production is quite irregular. On an average, white pine bears seed every four years and Norway pine every seven years, while jack pine produces seed every year. Balsam fir also produces some seed every year. Seed years are not uniformly distributed over the Lake states. Investigations show that the distribution of seed is very much localized, that is, in many parts of the state seed may be abundant, while in other parts they are scarce.

SEED COLLECTION

Several methods of collecting seed have been tried and results show that jack pine cones can be collected from squirrel hoards more cheaply than from trees. Cones were collected from jack pine trees that were felled, from those that were heavily loaded with cones and were cut down in order to get them, and from squirrel caches.

About two bushels of cones can be gathered in a day by one man from trees which must be cut down; and from two to three bushels from trees which are already down; while the average for two men for ten days was between four and five bushels a day for each man, from squirrel caches. Squirrels do not often hide jack pine cones when they are first cut, but heap them up in piles of from half a bushel to a bushel. It is only necessary to go around and scoop them up. The squirrels seem to prefer tall trees and the largest number of cones was obtained in stands of jack pine which were above average height. A very heavily loaded jack pine tree will yield about a bushel and a half of cones.

In collecting Norway pine cones, the best method found is to follow the sawyers in logging camps in a region where seed are abundant. If this is impossible, the next best method is to collect the cones from the squirrel caches. In contrast to their method in the case of jack pine cones, the squirrels hide Norway pine cones within a few hours after dropping them from the trees. This makes it necessary to hunt in the leaves and around log and brush piles for them, and consequently this is much slower work than collecting jack pine cones.

In a good seed year a Norway pine tree will yield from one bushel to two bushels of cones, and it will take a man about two and a half hours to pick a bushel of cones from a felled tree under ordinary logging conditions.

White pine cones can be collected either from standing trees or from trees felled in a summer logging camp. The latter is the cheaper method, but when it is impossible to find camps in stands of white pine which have a good seed crop, the other method is necessary.

By following the saw crews in a good year, a man can pick as much as 600 pounds of cones a day, or about fifteen bushels. In good situations, one man can collect eight or ten bushels from the tops of standing trees. As the cones are generally on the ends of the topmost branches, the usual method of collecting them from standing trees is to climb the trees with the aid of climbers and then break off the branches bearing cones with a long pole having a sharp hook on the end. White pine branches are very brittle and are easily broken. On the other hand, Norway pine branches are very limber and hard to break, and the cones are hidden from the man in the tree by tufts of needles at the ends of the branches.

The average prices paid for collecting cones are about as follows: For Norway and jack pine the minimum is about a dollar and a half per hundred pounds; for white pine it is sometimes as low as 80 cents. The cones of jack pine are much smaller than those of Norway pine but do not bring a higher price because the jack pine cones can be collected at all times of the year. The cones seldom open and the seeds remain in the cones for many years after they are ripe.

After the cones are collected they are put in sacks and stored in a large room, only one tier deep. This allows the air to circulate around them. If they are green or wet, it is sometimes advisable to spread them out in a large room and shovel them over every day for a short time. One of the main points in storing cones is to put them where red squirrels and chipmunks will not get at them. These little animals will find the smallest opening and will destroy a good many dollars' worth of seed in a short time.

The quality of the seed varies considerably with the kind of year. When conditions are right for a good crop, the quality is high.

An average Norway pine cone contains thirty-seven seeds. In a poor year, from fifteen to twenty-five per cent of these are worthless, owing to fungous diseases and to insects which lay their eggs in the ovules of the seed. In a good year, the percentage of poor seed is very much less. An average jack pine cone contains about thirty seeds. About twenty per cent of the seeds of jack pine are bad, because some of the cones are often fifteen years old or more.

As the cones open in drying, the number in a bushel, of the different species, varies considerably. A count gave the following figures:

White spruce	12,730
White pine	330
Norway pine	1,240

The size of jack pine cones varies so much that no reliable figures can be given. Generally speaking, a bushel contains between four and five thousand cones.

SEED EXTRACTION

Heat is necessary to get the seed out of the cones. In some places the cones are spread out in trays and subjected to the heat of the sun. This method is all right when the days are warm and there is very little likelihood of rain, but as many days are cloudy and rainy in the northern country, especially in the fall when most of the seed is extracted, this method gives very poor results. The best results are obtained from the use of a sort of kiln heated by a furnace or stove, into which are put trays containing the cones. To determine the optimum degree of heat for the best results in extracting pine seed, experiments were carried on in which cones were heated at varying temperatures, grading from 105 to 175 degrees, Fahrenheit, by five-degree intervals.

The time required to start cracking, the time required for the cones to open, and the percentage of cones which did not open were determined.

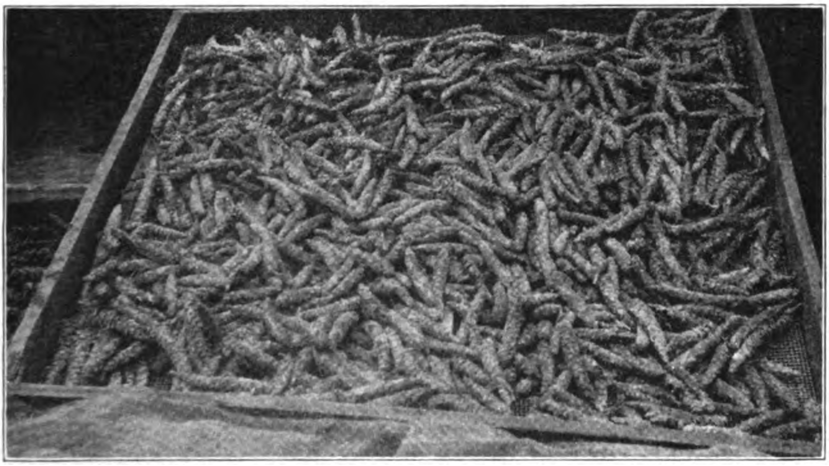

Fig. 8. Tray of White Pine Cones Before Heating

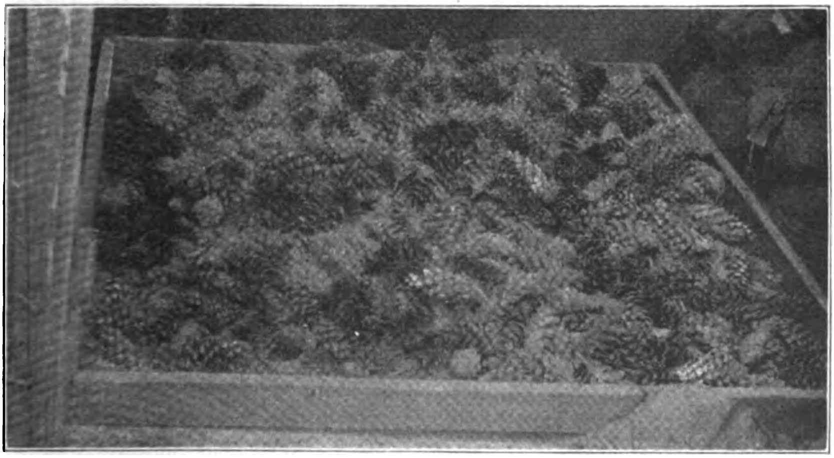

Fig. 9. Same Cones After Being Heated
Note increase in size. Too many cones should not be put in one tray.

These tests show that from 135 to 140 degrees is the best temperature for extracting jack pine seed. While a higher temperature shortens the time of heating somewhat, the difference is not enough to warrant the consequent lowering of germination. Below 135 degrees the time required is much greater and the amount of labor and fuel is correspondingly large, while a considerable percentage does not open at all. One noticeable thing brought out by this experiment was that new cones of jack pine open faster than those which have remained on the trees for many years, and few of the new cones remained closed after heating. Therefore it seems advisable to collect new cones whenever possible.

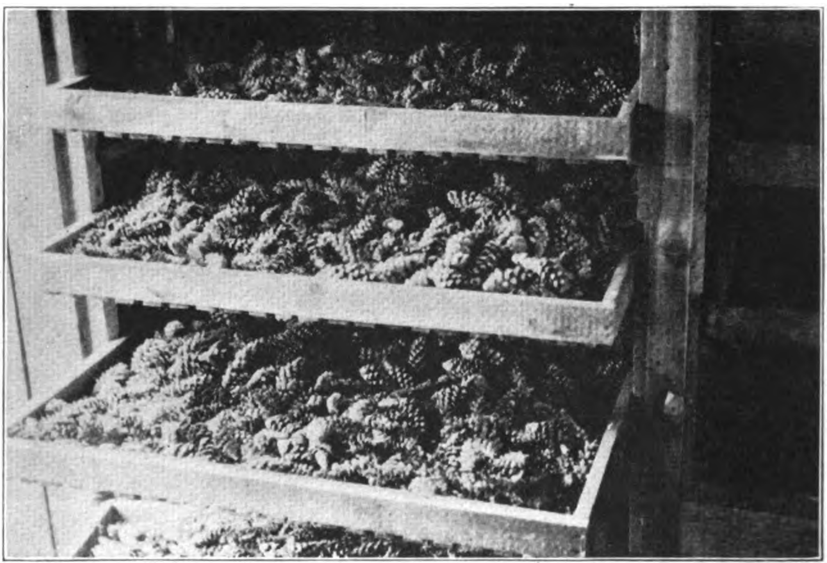

Fig. 10. Trays of Cones Ready for the Shaker

Soaking jack pine cones in order to hasten their opening does not give results which warrant the trouble.

With Norway pine cones, also, a temperature of 135 to 140 degrees gave the best results. As Norway pine cones naturally release their seeds when heated by the sun, no absolute time can be given for opening, the length of time depending primarily on the condition of the cones. When partly dry the cone scales open only about half way and it is very hard to get the seed from the cones no matter how much more they are heated. The best way to treat these cones is to sack them, put them into a barrel of water for a minute or two, drain them, put them on trays, and heat them immediately. The moisture causes the cones to close up tight and when they reflex they will open wide enough for the seed to be shaken out. The germination of seed extracted at different temperatures is given in Table I.

TABLE I

GERMINATION TEST*

Extraction temperature	Average germination	
	Jack pine	Norway pine
Degrees	Per cent	Per cent
100	59	..
110	69	..
115	72	..
125	..	75
130	90	85
135	75	81
140	80	69
145	71	71
150	70	72
160	57	..
165	51	65
170	..	35

* The germination test of these seed was made immediately after they were extracted. It is possible that seed extracted at higher temperatures would show a lower percentage of germination if allowed to remain exposed to the air until the moisture evaporated, as would be the case if some of the seed coats of those extracted at the higher temperatures were cracked.

It must also be noted that the seed remained within the cones and were protected by the cone scales and the seed wings, so that they were not directly exposed to the heat.

The low germination of the seed extracted at the low temperatures is probably due to the fact that the cones were not dry enough to fully reflex the scales and the plumper and better seed were not released.

All of these tests were carried on with a drying oven of one bushel capacity, in which it was possible to control the heat and the temperature remained constant. In actual practice on a large scale, the drying process takes considerably longer, because the cones are often piled on top of each other in the trays.

SEED CLEANING

A great deal of foreign matter, resin, wings, broken scales, and needles, is found in the extracted seed. This must be removed, and a fanning-mill with the proper sieves is the best means for doing this. Before the seed are put into the fanning-mill the wings should be removed. This is done by running the seed between two rollers covered with corrugated rubber matting, or by spreading them on the floor two or three inches deep, in sacks, and tramping them with rubber-soled shoes. This will not injure the seed but will loosen most of the wings. The seed are then run through the fanning-mill twice. Special screens are necessary for coniferous seed, as many of the screens used for grain are not the right size. All screens should be made of zinc because the needles catch in wire screens and block up the holes. The following sizes are recommended: For white pine the holes in the top screens should be 16/64, 13/64, or, in some cases, 24/64. The lower screen will give best results if a 10/64 round-hole screen is used and then changed for a 3½/64, three fourths of an inch long, for the second screening. For Norway pine the same screens can be used, except that the bottom screens should be 10/64 and 5/64, three fourths of an inch long.

The clean white pine seed averages about 60 per cent of the original mixture, and Norway pine seed a trifle more.

The amount of seed that can be obtained from a bushel of cones varies from year to year. In a good seed year the seeds are plump and heavy; while in a poor seed year some of them are likely to be hollow. In a good year, white pine yields nearly a pound of seed to a measured bushel of cones. In 1915 the white pine extracted at this Station yielded fourteen ounces per bushel. Norway pine averages from eight to ten ounces to a measured bushel, while jack pine yields six or seven ounces.

STORAGE

After the seed have been cleaned they should be stored in large earthenware crocks with close-fitting tops. These crocks should be put in a cool place having an even temperature until the seed are needed. At this Station seed have been stored in closed Mason jars, tin cans, and other receptacles, but where any considerable quantity is used, five- and ten-gallon crocks with close-fitting tops are the most satisfactory.

NURSERY PRACTICE

Various experiments have been inaugurated to determine the optimum methods for raising the best stock in the nursery at the lowest cost.

The Station now produces one million transplants annually for state plantings, and better methods of nursery practice make a tremendous difference in the quality of stock and the cost. The following experiments have been carried on and the results of each are given. In all of these experiments the seed were very thoroly mixed and an equal number was sown in plots a foot square, distributed systematically throughout a seedbed. The results given are based on the average of these plots.

TIME FOR SOWING

Experiments have been carried on with white spruce, Norway spruce, white pine, Norway pine, Scotch pine, jack pine, and western yellow pine. The seed have been sown April 15, May 1, May 15, June 15, July 15, and October 15.

The conclusions have been based upon the weight of the seedlings the first and second year, the length of top and root produced, and the density of growth per square foot of ground. This experiment has been carried on for three years with most of the species, and for two years with the others. The summary of the results is as follows:

White pine germinated much more uniformly when sown in the fall and allowed to lie in the ground during the winter. Norway pine gave equally good results with fall or early spring sowing. Jack pine and Scotch pine gave much better results from spring sowing, probably because the seeds of these species germinate very quickly. A few warm days in the fall caused many of them to swell, and the freezing weather later killed them. Spruce gave better results from spring sowings, altho some species, especially white spruce, are very erratic.

The time of sowing seems to affect the percentage of damping-off. Many of the seeds in the fall-sown beds germinate during the cool, moist weather of the early spring. This seems to be especially favorable to certain damping-off fungi. Seed sown in summer germinate much more quickly, but make poor development by fall and in some cases the stock was almost a year behind that obtained from fall-sown seed.

The effect on germination of sowing at different times is shown by the results obtained with jack pine. The number of days required for seed to sprout when planted at different dates is as follows:

Date	Days	Date	Days
April 15	35	June 15	15
May 1	25	July 15	11
May 15	16	October 15	215

The average temperature of the ground at the depth the seed was covered, from the time of sowing to the day of sprouting, was as follows for Norway pine:

Date	Degrees	Date	Degrees
May 1	59.6	June 15	69.2
May 15	67.9	July 15	77.5

This shows quite conclusively that the temperature of the soil is one of the main factors in the length of the germination period, and any cultural methods which may be used to increase the temperature of the soil should increase the uniformity and amount of germination. The size of the seedlings is best shown in Figure 11.

Norway pine germinated in 17 days when sown July 8, and white pine in 25 days. When sown April 15, 72 days were required for Norway pine seed to germinate and 73 days for white pine. The increase in germination hardly made up for the lack in size of the seedlings. The results of these experiments are shown in Tables II and III.

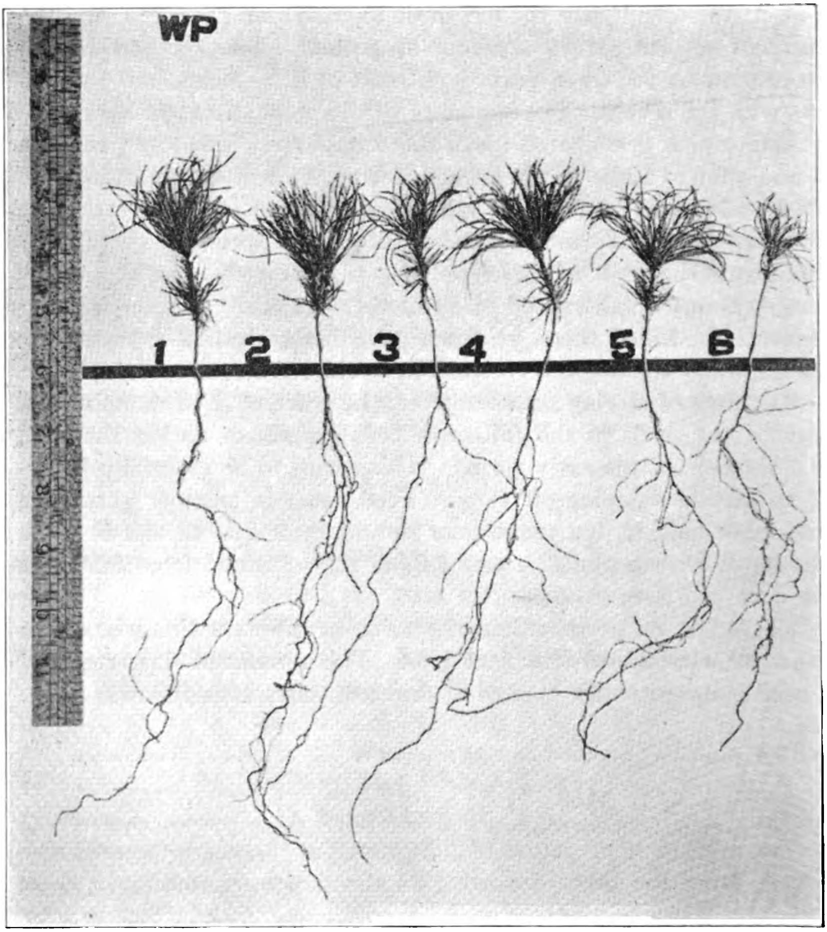

Fig. 11. White Pine Seedlings From Seed Sown on Different Dates

1. Oct. 15, 1913
2. April 15, 1914
3. May 1, 1914
4. May 15, 1914
5. June 15, 1914
6. July 15, 1914

With the later sowing the Norway pine seedlings came up all through the season and a great many of them were killed in the fall. A great many of the seedlings in the September bed germinated in the fall and most of them were killed. Results show that fall sowing, if done at all, should be done very late, so that the seed will not have a chance to sprout. Otherwise sowing in April or the first of May will give the best general results.

TABLE II

Effect of Different Dates of Seeding on Germination

	Time of Seeding						
	Sep. 15	Oct. 15	Apr. 15	May 1	May 15	June 1	July 8
Norway pine							
Mean soil temperature from time of sowing until germination, degrees*	62.3	......	57	55.3	65.4	62.3	69.9
Days for germination	40	†	72	54	40	31	17
White pine							
Mean soil temperature, degrees	62.3	......	57	55.6	65.4	62.6	70
Days for germination	40	†	73	61	40	34	25
Scotch pine							
Mean soil temperature, degrees	57.7	......	57	......	......	......	......
Days for germination	29	†	72	......	......	......	......
Norway spruce							
Mean soil temperature, degrees	......	......	......	56.5	60	56.6	70
Days for germination	......	......	......	56	38	28	14

* The mean temperature is the average of the readings taken in the morning and evening from soil thermometers placed at the depth of the seed. A soil thermograph would have given better results. The mean temperature in this case was not very indicative; a period with abnormally high and low temperatures will hasten germination more than a period of more uniform temperatures, altho the mean temperature in both periods may be the same.

† Spring.

TABLE III

Effect of Different Dates of Seeding on Development and Density

	Time of Seeding						
	Sep. 15	Oct. 15	Apr. 15	May 1	May 15	June 1	July 8
Norway pine							
Per cent damped-off	......	**	‡	‡	‡‡	‡	‡
Condition of seedlings	††	*	*	*	*	*	†
White pine							
Per cent damped-off	‡	‡	0	0	0	‡	......
Condition of seedlings	*	***	*	§	§	*	†
Scotch pine							
Per cent damped-off	......	**	......	......	......	......	......
Norway spruce							
Per cent damped-off	......	......	......	‡‡	‡	‡	‡
Condition of seedlings	......	......	......	‡	‡	§	†

* Good. ** Large. *** Fine. † Poor. †† Very poor. ‡ Small. ‡‡ Very small. § Uneven.

The best white pine seedlings were produced from fall sowing, altho the sowing in May gave good results. Sowing late in July resulted in very uneven germination and the loss of a great many tender seedlings.

The seed of Scotch pine sown in the fall germinated in a short time and all of the young seedlings were killed by the frost. It seems very conclusive from this experiment that fall sowing of Scotch pine will not give good results.

Seed of Norway spruce sown earliest in the season produced the best plants, altho they were covered too deeply. The seed sown in the latter part of the season produced a very uneven stand.

FERTILIZERS

Manure, muck, tankage, acid phosphate, and nitrate of soda were used on the experimental beds to determine the advisability of using one of these fertilizers in the nursery beds to hasten the growth and development of the stock. The results obtained thus far have been somewhat contradictory, as Table IV shows. These experiments will be continued until results are obtained which will show definitely whether it is advisable to use fertilizers.

TABLE IV

EFFECT OF FERTILIZERS

	Manure	Peat	Tankage	Acid phosphate	Nitrate of soda	No fertilizer
Norway pine						
Weight first year, per 100, grams	24.7	17.8	20.9	21.3	19.7	21.3
Weight second year, per 100, grams	64.0	73.1	64.3	40.8	47.6	76.6
Length first year, inches	10.3	10.6	9.7	9.2	9.0	10.4
Length second year, inches	11.5	13.9	13.1	10.5	12.3	11.5
Number of seedlings per square foot, second year	353	218	153	377	369	328
White pine						
Weight first year, per 100, grams	26.9	20.4	19.8	......	14.3	19.3
Weight second year, per 100, grams	58.8	54.7	67.5	57.0	33.5	68.8
Length first year, inches	9.8	9.8	9.2	....	9.0	9.6
Length second year, inches	12.3	12.8	13.0	12.1	12.5	12.6
Number of seedlings per square foot, second year	152	130	94	41	136	189

COVER FOR SEEDBEDS

The experiments reported in Table V have been conducted for two years with balsam fir, white pine, Norway pine, Scotch pine, and white spruce to determine the depth of cover in the seedbed which will give the best stand. It will be seen that depth of cover is the most important factor in securing evenness and a high percentage of germination.

The Norway pine seed covered ¼ inch germinated the most uniformly, with the least loss from damping-off. More damping-off resulted from ⅜ inch cover, but this stand was also very good. The seed covered ½ inch were a total loss, owing to poor germination and serious damping-off. A covering of not more than ¼ inch is recommended.

The white pine seed covered ½ inch germinated best and the plants were most uniform in appearance. Those covered more deeply germinated more unevenly and were most injured by damping-off. A covering from ⅜ to ½ inch deep is recommended.

The seed of Scotch pine covered ⅛ to ¼ inch deep produced the best looking seedlings, and germinated most uniformly. Those covered ½ inch were uneven and undersized and much affected by damping-off. A covering of ⅛ to ¼ inch is recommended.

A covering from ⅛ to ⅜ inch deep is apparently best for Douglas fir seed. Those covered ½ inch were more irregular in germination, size, and development, and the seedlings continued to appear all summer.

The condition of the seedlings of western yellow pine in all of the beds was very good at the end of the season. Some of the seedlings that were covered ¾ inch had their seed-coats brushed off in coming through and some were less vigorous than those with lighter cover.

The balsam fir seedlings were quite small at the end of the season, altho those with the lighter covering were more advanced. Some means should be tried to secure an early germination, either sowing in the fall or some treatment of the seed. It appears that a covering of not over ⅜ inch is best.

Small worms were quite destructive in all of the white spruce beds during the latter part of July. Starting at the top, they ate all the leaves off the seedlings and sometimes ate the upper part of the stem.

Some method should be worked out to secure rapid germination. Sixty-five per cent of the seed in the bed with ⅛ inch cover and over forty per cent of those covered at other depths germinated one hundred days after sowing. One fourth inch depth gave the best results.

The results with jack pine were very similar to those obtained with Scotch pine, the only exception being that in some cases results indicated that a slightly lighter covering should be applied to jack pine.

TABLE V

RESULTS WITH DIFFERENT DEPTHS OF COVER IN SEEDBEDS

	Norway pine				White pine				Scotch pine				Douglas fir§			
	Inch				Inch				Inch				Inch			
Depth of cover	1/8	1/4	3/8	1/2	1/8	1/4	3/8	1/2	1/8	1/4	3/8	1/2	1/8	1/4	3/8	1/2
Days to germinate ..	32	35	38	42	38	38	41	43	30	31	33	34	19	23	23	23
Seedlings per sq. ft. 1 mo. after germination..	161	281	256	98	87	113	59	73	101	117	74	83	113	112	97	175
Seedlings per sq. ft. at end of season..	174	280	257	34	144	145	164	160	102	120	72	82	322	363	380	339
Effect of damping-off	*	**	†	††	*	‡	‡	†	*	*	*	‡	...	...	...	...

TABLE V—*Continued*

RESULTS WITH DIFFERENT DEPTHS OF COVER IN SEEDBEDS

	Western yellow pine§				Balsam fir§				White spruce§			
	Inch				Inch				Inch			
Depth of cover....	1/8	1/4	3/8	1/2	1/8	1/4	3/8	1/2	1/8	1/4	3/8	1/2
Days to germinate..	....	....	....	....	24	26	26	28	26	26	26	32
Seedlings per sq. ft. 1 mo. after germination	199	198	260	231	77	34	32	6	40	156	159	81
Seedlings per sq. ft. at end of season..	223	201	306	236	104	70	57	14	90	352	274	156
Effect of damping-off	....	....	....	....	**	**	**	**	....	....	....	....

* Light. ** Very light. † Severe. †† Very severe. ‡ Medium.
§ Time of sowing: May 12, 1914.

SHADE

The results from the experiment with shade are given in Table VI.

In the "half shade" plot of white pine, germination was uneven and a considerable number of seed germinated late in the season.

In the "no shade" plot, the stand was fairly even and the seedlings appeared to be in as good condition as in the shaded bed, except that they were a lighter shade of green than the others.

The seedlings of Norway pine in the "quarter shade" and "no shade" plots were much superior to those in the "half shade" plot. These beds were affected by both early and late damping-off, and in the early part of the season the unshaded bed was the most affected, but in the latter part the "half shade" bed was badly affected while the unshaded one was not touched. The "quarter shade" plot showed effects intermediate between the other two.

To all appearances the "no shade" plot of Scotch pine contained as good seedlings as the other beds. The "half shade" plot produced quite a large number of late-germinating seedlings which will make a more uneven stand than the unshaded plot.

TABLE VI

EFFECT OF SHADE ON THE DEVELOPMENT OF SEEDLINGS AND ON DAMPING-OFF

	White pine			Norway pine			Scotch pine		
	Half shade	Quarter shade	No shade	Half shade	Quarter shade	No shade	Half shade	Quarter shade	No shade
Seedlings per sq. ft. 1 mo. after germination	31	39	48	193	185	100	110	75	75
Seedlings per sq. ft. at end of season	62	103	84	187	191	102	102	83	78
Weight of seedlings per 100, grams	4.9	6.1	6.8	6.0	6.9	10.2	9.0	11.9	11.5
Total length of seedlings, inches	6.7	8.5	8.0	8.1	7.3	8.7	7.2	7.9	8.6
Effect of damping-off	*	*	†	§	†	*	†	†	†

* Medium † Slight. ‡ Very many. § Severe.

MULCHES

Experiments have been conducted for a considerable time to determine the effect and desirability of mulching the seedbeds after sowing. The results indicate that mulching is very desirable. Table VII shows the results obtained from using sphagnum moss and burlap on the different species.

TABLE VII

MULCH FOR SEEDBEDS

	White spruce			White pine			Norway pine			Scotch pine		
	Burlap	Sphagnum	No mulch	Burlap	Sphagnum	No mulch	Burlap	Sphagnum	No mulch	Burlap	Sphagnum	No mulch
Days to germinate	25	25	22	42	42	42	36	36	30	29	26	30
Seedlings per sq. ft. 1 mo. after breaking ground	60	46	35	48	55	42	208	214	176	86	74	78
Seedlings per sq. ft. at end of growing season	131	177	56	200	149	149	150	244	239	87	84	77
Effect of damping-off	‡	*	†	†	†	....	‡	†	*	†	*	†

‡ Very severe. * Medium. † Slight.

With white spruce, better germination resulted with sphagnum than with burlap. Germination was very poor where no mulch was used. It is recommended that white spruce be mulched with sphagnum moss, which should be removed gradually after germination.

The beds of white pine that were mulched are much better than the one that was not mulched.

Damping-off was very serious in the Norway pine plot in which the burlap was used. It was fairly serious in the bed which was not mulched, and slight with the bed mulched with sphagnum moss. The bed which was not mulched was inferior in appearance to the other two.

Very little difference was shown in the Scotch pine seedlings from the three different mulches, altho those not mulched did not look so well as those that were mulched.

PRELIMINARY TREATMENT OF SEED

A large percentage of white pine seed fails to germinate the year sown, or else straggles along throughout the season. This has always made it hard to handle in the nursery. Various methods have been tried to hasten its germination, and the one method which has shown the most promise is that of soaking the seed before sowing in the spring. The results from this procedure with white pine, Norway pine, and white spruce are shown in Table VIII.

TABLE VIII

Effect of Soaking Seed Before Sowing

	Norway pine			White pine			White spruce		
	Unsoaked	Soaked 2 days	Soaked 4 days	Unsoaked	Soaked 2 days	Soaked 4 days	Unsoaked	Soaked 2 days	Soaked 4 days
Length of germination period..	33	33	39	39	36	36	30	30	30
Number seedlings per sq. ft. 1 mo. after breaking ground....	236	205	172	38	113	50	86	154	97
Number seedlings per sq. ft. at end of growing season.......	246	252	213	95	190	79	183	243	155
Effect of damping-off...........	‡	**	**	*	‡	*	*	**	**

* Slight ** Very slight. ‡ None.

The Norway pine plot of unsoaked seed has the poorest appearance of the three. The stand is patchy and uneven, but germination was as good as in either of the others. The seed soaked two days made the best appearance of the three. The seed soaked four days produced the least number of seedlings to the square foot, but these looked better than those from the unsoaked seed. It is recommended that where late spring sowing is done, at least part of the Norway pine seed be soaked two days to see whether results are conclusive.

Results show very conclusively that white pine seed soaked two days gave much better results than the unsoaked seed, both in germination and appearance of stand. It is recommended that white pine seed sown in the spring be soaked for two days.

The white spruce seed soaked two days was far the best of the three plots. The seed not soaked dragged along in germination more than those in the other two plots. The seed soaked four days did not do so well as the seed soaked two days. It is recommended that white spruce seed be soaked two days before sowing in the spring.

DENSITY OF SOWING

An experiment was conducted to discover the maximum number of seedlings to raise in a seedbed without injuring their development by crowding, and at the same time utilize the space so as to get the greatest number at the smallest cost. This experiment has not progressed far enough to give definite conclusions, but results to date are shown in Table IX.

Very little damping-off occurred in any of the plots of white pine. The seedlings in all were in good condition. The first year does not show the effect of competition and it will be necessary to count and measure these plots the second year in order to show the number of seedlings which it is best to raise per square foot under conditions in the Cloquet nursery.

TABLE IX

AMOUNT OF SEED PER SQUARE FOOT FOR MAXIMUM NUMBER OF SEEDLINGS WITH THE BEST DEVELOPMENT

	White pine					Norway pine				
Seed per sq. ft.	200	400	600	800	1000	200	400	600	800	1000
Seedlings per sq. ft. at end of season.........	90	180	347	339	410	171	323	495	518	566
Weight of seedlings per hundred at end of season, grams	8.1	6.6	6.2	6.0	6.1	7.6	5.1	.....	4.4	5.0
Length of seedlings at end of season, inches.	7.1	6.6	5.9	6.1	6.0	6.0	6.1	.....	6.6	6.8

The thicker the seedlings the more serious was the damping-off in the Norway pine plots. No damping-off resulted in the plot sown to 200 seed. Very few traces were apparent in the plot with 400 seed. Damping-off was moderate in the plot with 600 seed and very serious in the plots with 800 and 1,000 seed to the square foot. Three-fourths of some of the plots were destroyed. Competition the first year is not so keen as it will be the second year. The two thicker plots showed evidences of overcrowding and there were many short seedlings of apparently the same age as the others.

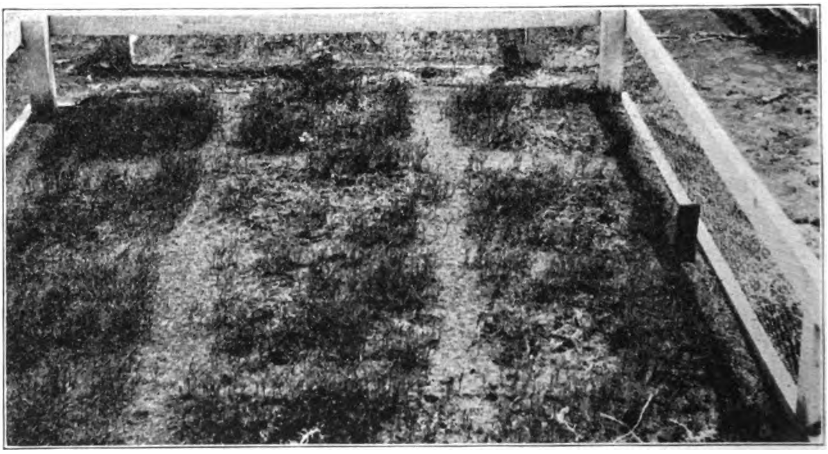

Fig. 12. Ravages of "Damping-off" Fungus in Experimental Bed

DAMPING-OFF

As the preceding experiments show, damping-off has been a very serious drawback in raising seedlings. Experiments have been conducted for the last two years aiming at the solution of this problem. Results were somewhat contradictory, and the subject was taken up very intensively in 1916 to see if it is possible to determine the best way to combat damping-off. A coöperative agreement has been entered into with the Division of Plant Pathology and Botany at University Farm, and a specialist assigned to the Station to work on the pathological side of the case, while all of the cultural methods that

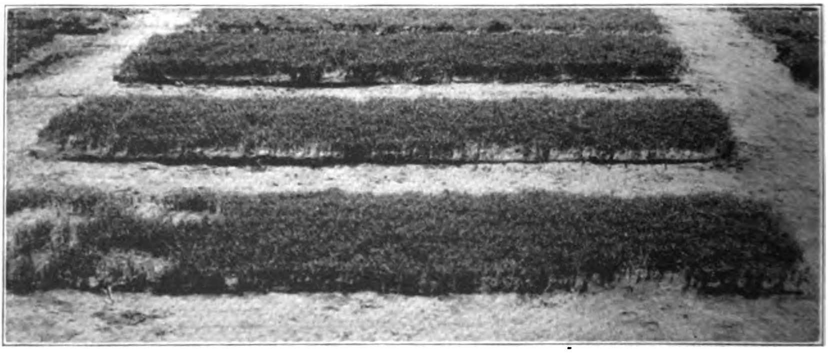

Fig. 13. Two-year-old Seedling Beds
The vacant spots show the effect of damping-off the previous year.

may influence the disease are being tried. It is hoped that this problem will soon be very definitely solved for this region.

SOWING SEEDBEDS

Figures 14 to 44 inclusive show the way in which equal covering of the seed throughout the seedbeds is obtained and the different methods of transplanting. Some of these methods have given very good results.

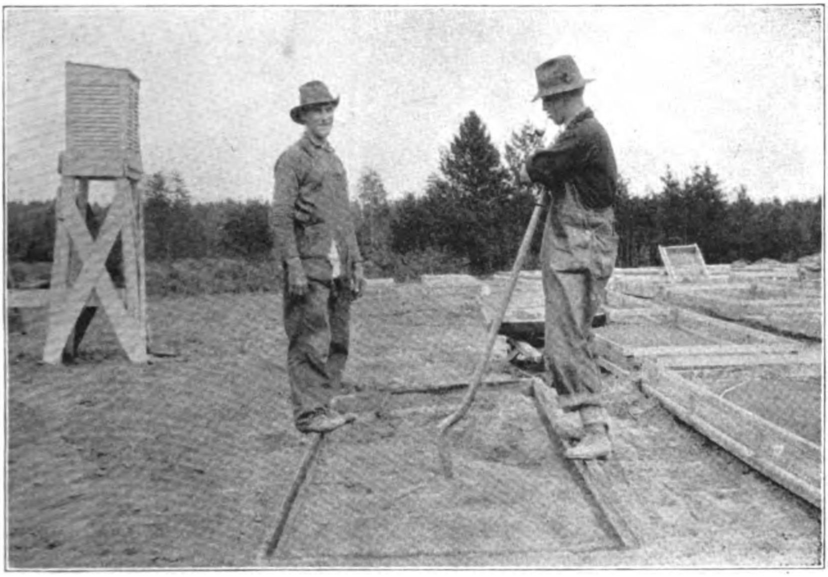

Fig. 14. Preparing the Seedbed

The 4x12 foot form made of 2x4s is first lined up in proper position with respect to the other beds and then stood upon to make a print in the earth, showing the future position of the bed. The form is then laid to one side, and the place marked by the form is spaded to a depth of from one foot to two feet and all sticks and stones are thrown out.

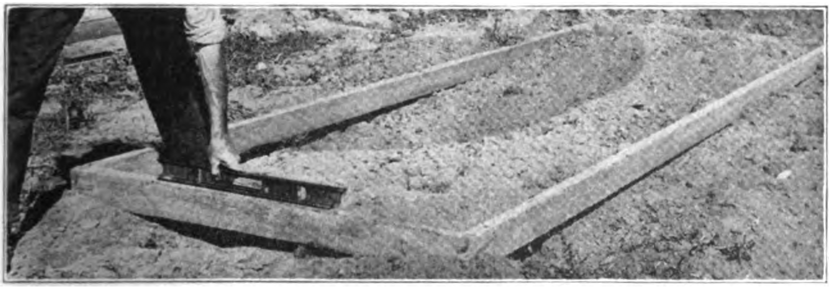

Fig. 15. Preparing the Seedbed

The form is placed in position again and leveled with a spirit level. Any surplus soil needed to fill the form is now added. Note the level on the frame. When one side and one end are level the whole frame will be level, as it is rigid.

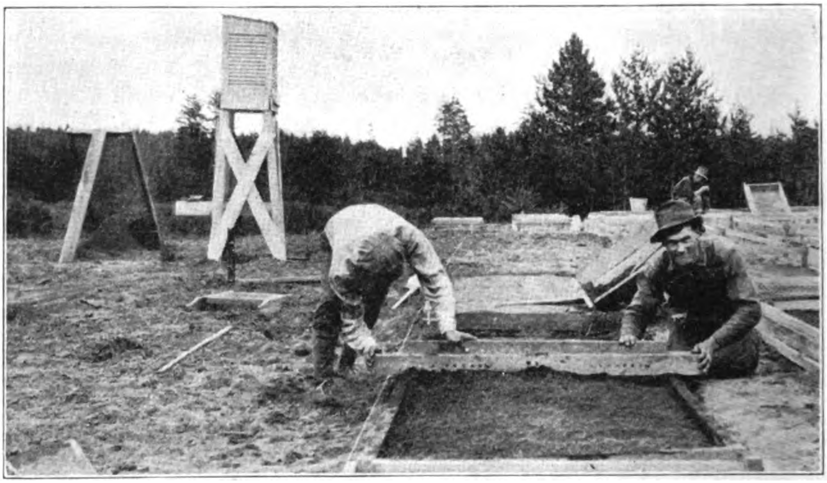

Fig. 16. Preparing the Seedbed

After the bed is filled and leveled, it is gone over with a concave scraper which smooths the surface and at the same time slopes the bed slightly from the center for drainage. As the frame is level and the scraper travels on the frame, the surface of the bed is always horizontal and there is no chance for any washing of the soil or collecting of water in pockets.

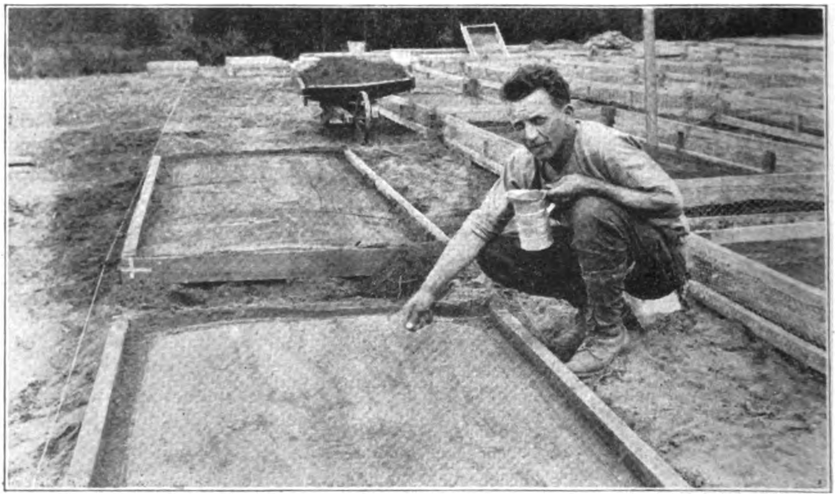

Fig. 17. Sowing the Seed Broadcast

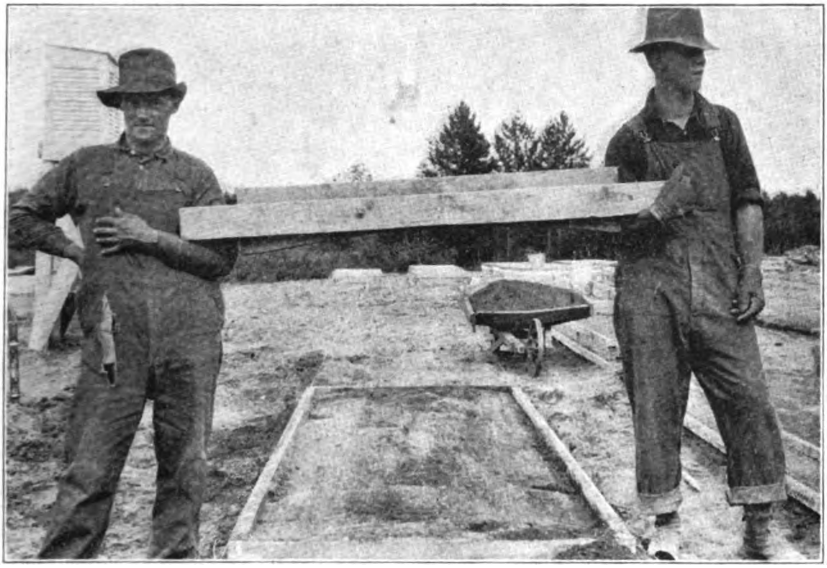

Fig. 18. Bed After the Scraper Has Gone Over It
Note surplus soil scraped off at end and construction of scraper in detail.

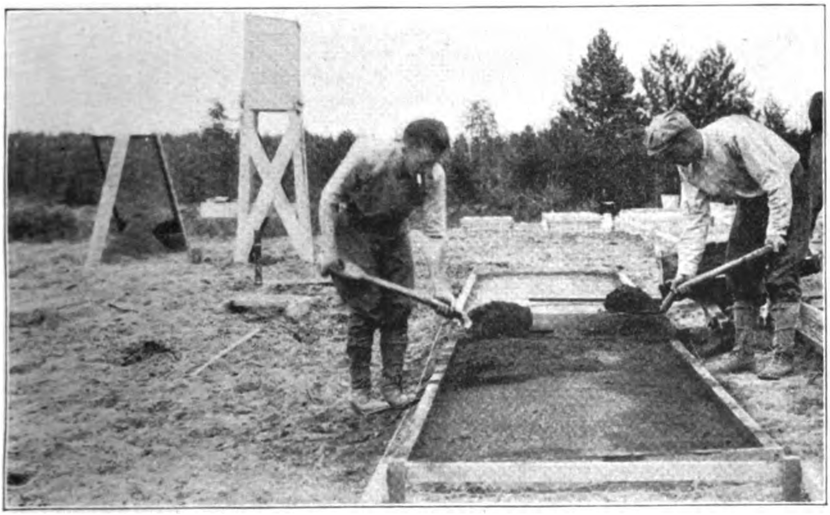

Fig. 19. Covering the Seed
The seed are covered with finely sifted soil or sand which is scattered on with shovels. If the soil is very dry and there is a tendency for the seed to push ahead of the scraper, the soil is lightly sprinkled before the seed are sown. This causes the seed to remain in place. Note the screen for sifting the soil.

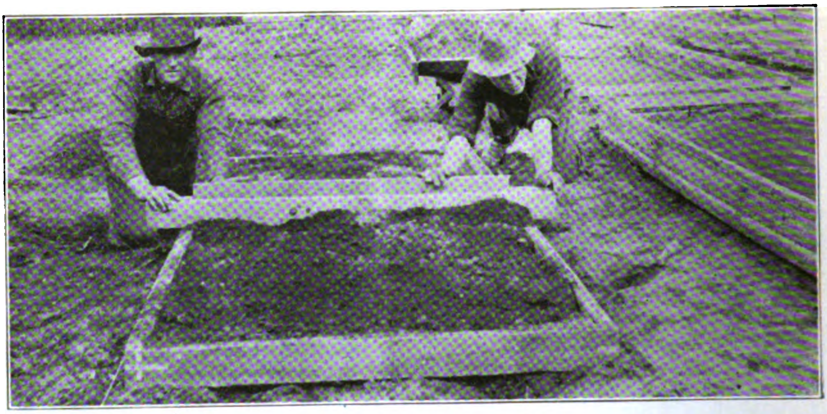

Fig. 20. Covering the Seed

When the soil is distributed on the bed it is not necessary to scatter it on evenly as the seed is uniformly covered by going over it with a scraper, the tongue of which is exactly like that used to make the surface of the bed. This scraper can be raised or lowered by means of blocks which are fastened to the scraper where it runs on the frame. Any surplus soil is pushed off and all spots not covered are filled by the scraper as it is pushed along.

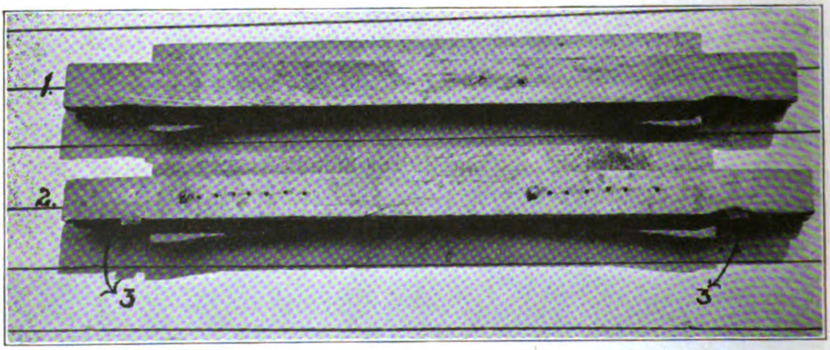

Fig. 21. Scrapers Used in Making Seedbeds
1. Scraper for leveling bed
2. Scraper for covering seed
3. Blocks which regulate depth of covering
These blocks are interchangeable, so that seed can be covered any depth desired.

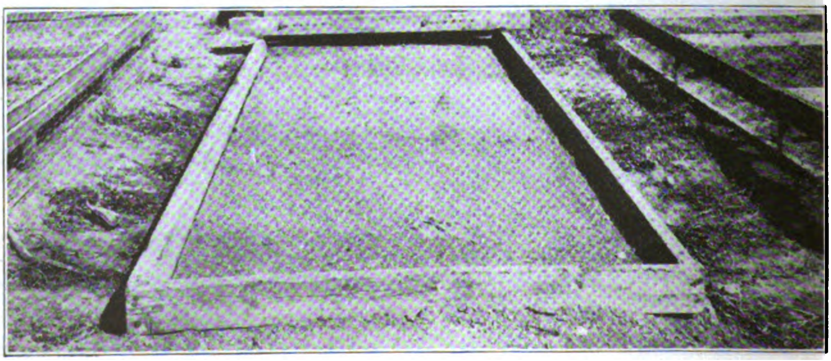

Fig. 22. Bed and Scraper After Seed Have Been Covered

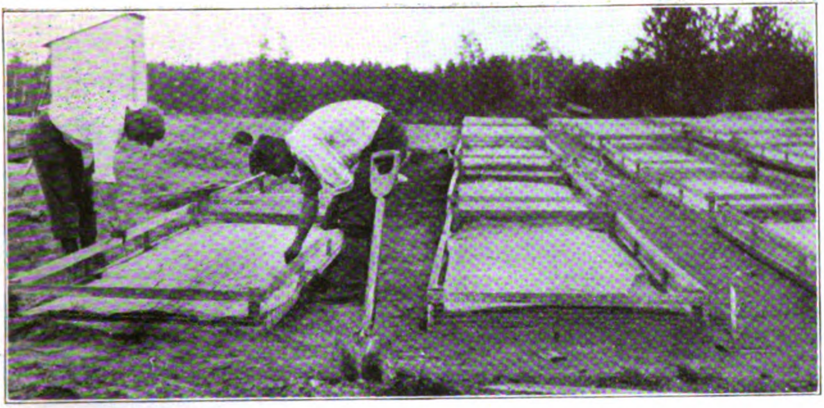

Fig. 23. Putting on Burlap After Bed Is Sown and Covered

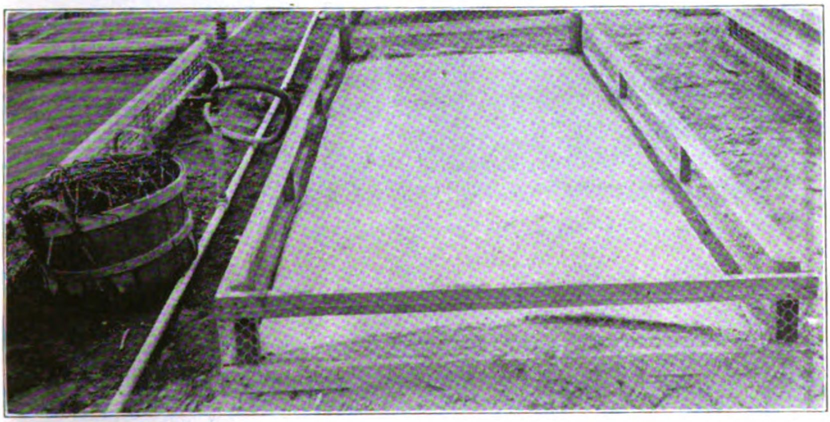

Fig. 24. Bed After Burlap Is Pinned Down

Note basket of pins made from telephone wire for holding burlap in place, also corner posts raised to hold top screen in place. The burlap prevents any washing of the soil and also prevents subsequent drying out, until germination.

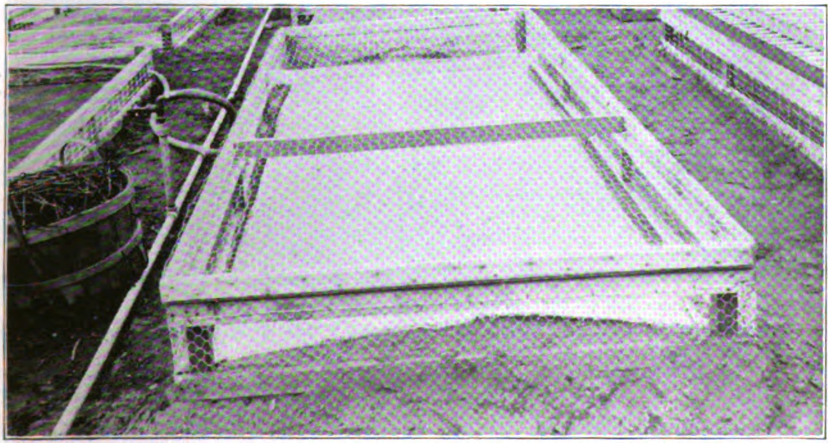

Fig. 25. Bed With Top Screen in Place

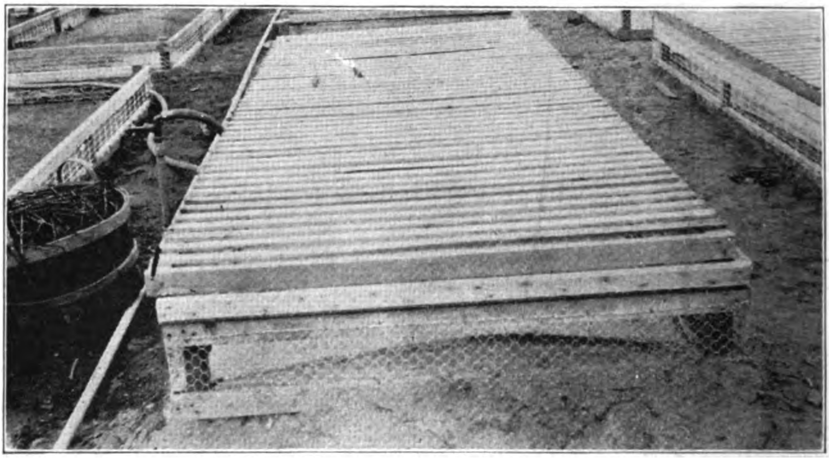

Fig. 26. Lath Shade Frame in Place and Bed Completed

Four men completed forty such beds in one day. This includes preparation of soil and beds, sowing seed, putting on frames, burlap, and screens, and cleaning up paths.

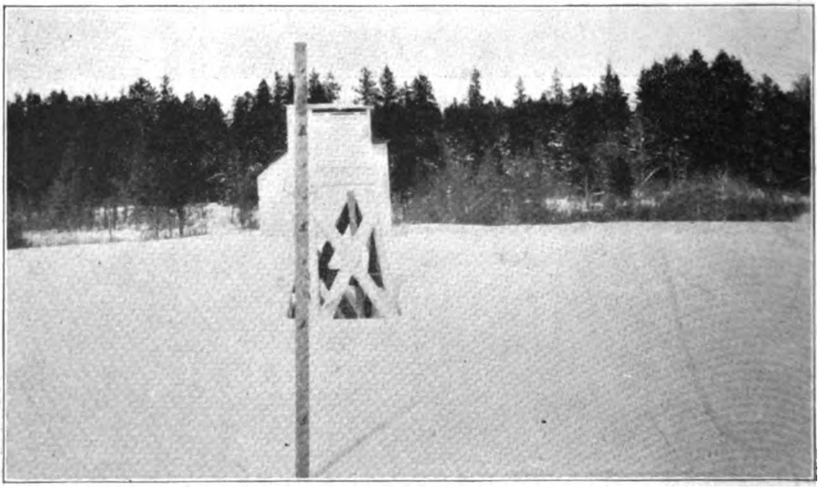

Fig. 27. The Nursery in Winter

No mulching is necessary, owing to heavy snow. The snow is trapped by trees surrounding the nursery.

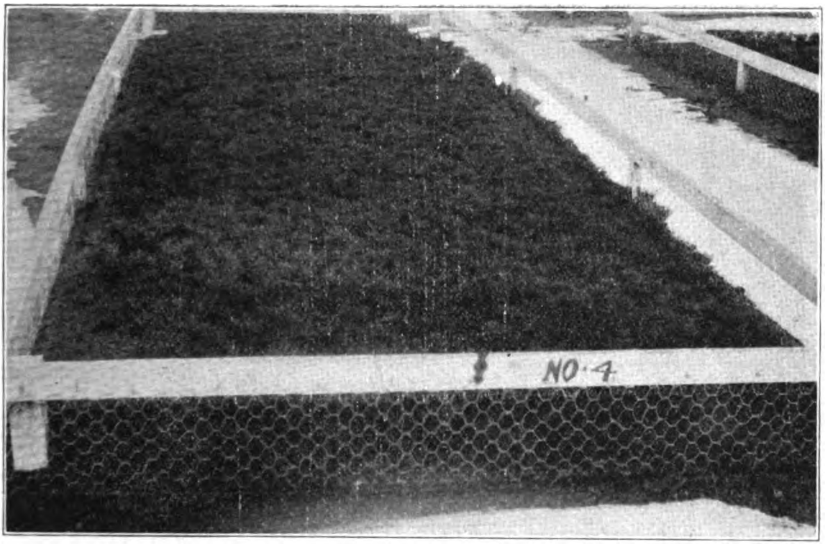

Fig. 28. Bed Containing 18,000 One-year-old Norway Pine Seedlings

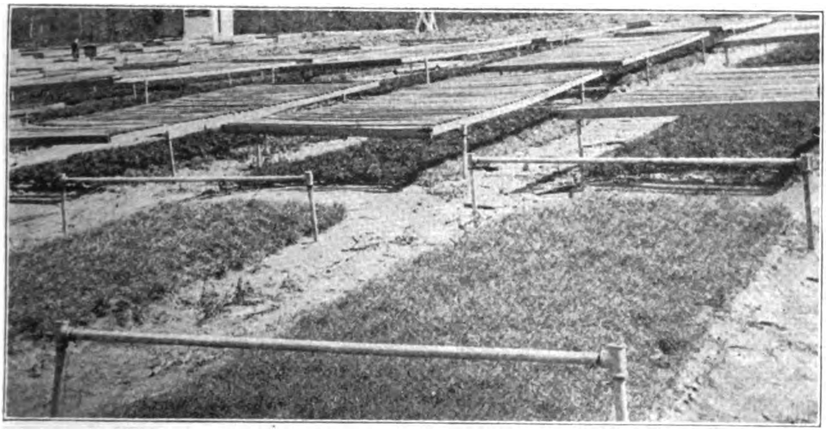

Fig. 29. Shade Frame Holders

These holders are made of half-inch galvanized pipe. They will last a long time and have proved much more satisfactory than the wooden holders previously used.

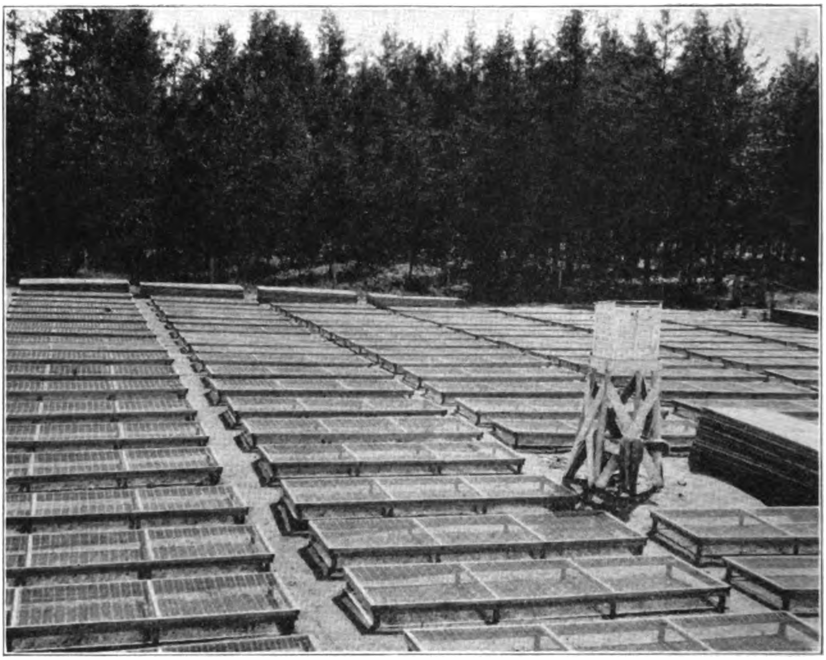

Fig. 30. Partial View of Nursery
There are 325 beds in the nursery at present.

TRANSPLANTING

Transplanting was first tried in 1912 by a method not generally used in nurseries. On account of the small size of the Norway pine seedlings and the flexibility of the stems, it was impossible to use a Yale planting-board, or any of the other devices commonly used. The amount of stock to be planted and the lack of laborers necessitated the use of some method that would get these seedlings in most expeditiously and at the same time warrant success. The plan adopted was as follows:

A furrow was plowed the length of the field and a very even, uniform edge from six to eight inches deep was left. A large plow was used, as no small one was available. The seedlings were taken up from where they had been heeled-in and put in buckets of water. Then, two men working in a crew, one holding the seedling in the proper position and the other making it secure by putting a handful of dirt against it, the seedlings were set very uniformly and rapidly. By this method, from 1,000 to 1,200 trees per hour can be set out. All that is necessary after the trees have been put in place is to plow back and push the soil up to them, then draw the soil into the furrow with a hoe and tamp it with the foot.

A seven-inch plow was used in 1913. This made the furrows from eight to ten inches apart, and allowed the use of a hand garden weeder between the rows, thus reducing weeding to a minimum.

The transplants of these years matured into fine, sturdy stock. With enough room to carry on this method, it is advantageous with certain kinds of stock. Boys are employed for this work at $1.50 per day.

In the spring of 1916, one million seedlings were transplanted. The method used was somewhat different from that used previously. The land was thoroly cultivated in the spring and harrowed and leveled. All of the trenches were made with trenchers weighing about 45 pounds each. These were made of ⅜-inch iron, sharpened, and could very easily be driven into the ground to a depth of eighteen inches.

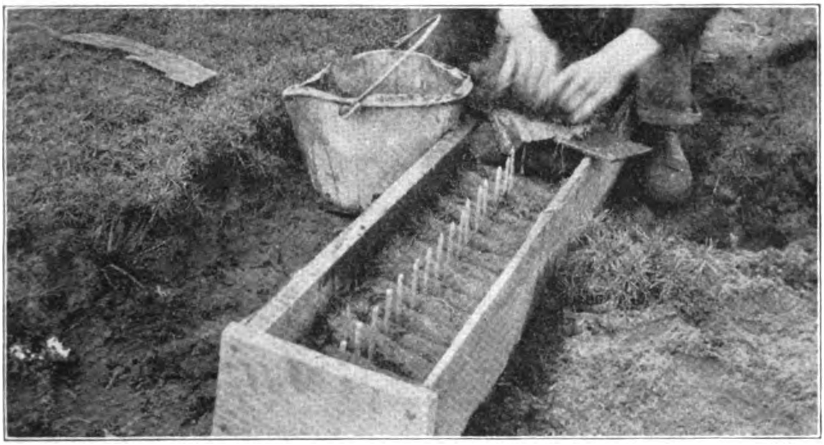

Fig. 31. Wrapping and Packing Seedlings

The seedlings are wrapped in wet burlap and put in boxes which have a row of 30d spikes to keep the bundles in place. The boxes hold between eight and ten thousand trees.

The seedlings were planted with a 6-foot planting board made of light lumber. Iron hinges were used. These kept the clamps very rigid and prevented the seedlings from falling out. Shelters were constructed of 2x4s and 1-inch lumber. These shelters were 16 feet long, 8 feet high, and 4 feet wide, and were covered with canvas or burlap to protect the roots of the young trees from the drying effects of the wind and sun. Each shelter accommodated two threaders. Each crew consisted of five men, two threaders, two planters, and one trench man.

The seedlings, when dug, were wrapped in bundles of about a hundred. Instead of tying the bundles, pieces of burlap about eight inches square, well soaked in water, were wrapped around them. They were then put into boxes. (See Figure 31.) These boxes were 8 feet long with a row of 30d spikes in the bottom. Each shelter accommodated two of these boxes. When filled, the boxes contained from eight to ten thousand young trees. These boxes were put just above the threading table in front of the threaders, on supports nailed to the 2x4s.

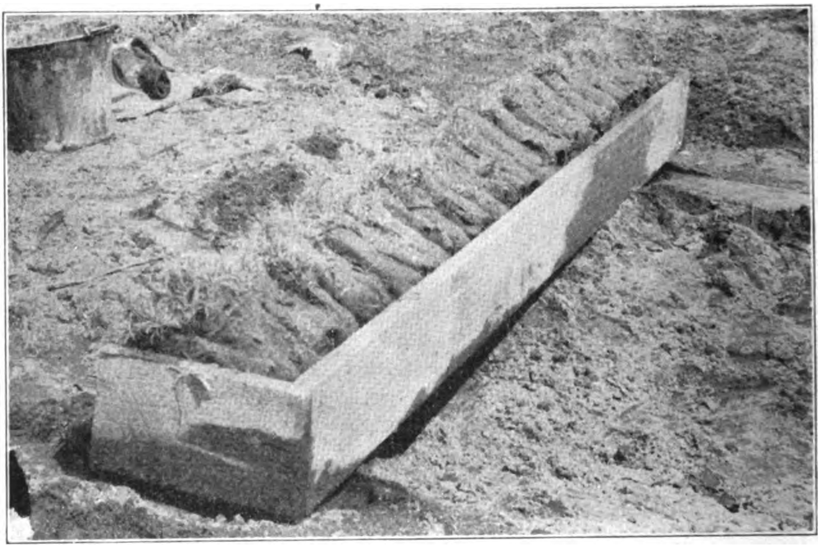

Fig. 32. Box Filled With Bundles of Seedlings

The young trees will remain moist for two days and if it is necessary to hold them longer they may be sprinkled.

When the work was begun the weather was so cold and the work so disagreeable that men quit daily. To increase the output and to keep laborers, the bonus system was initiated.

Under the bonus system, the men, including the trencher men and those engaged in hauling seedlings, averaged a little more than seven thousand trees a day. The cost of transplanting one million seedlings this year was 56 cents a thousand. This includes the transplanting of 1-0 stock[1] and many species of spruce, cedar, hemlock, and other varieties not so easily transplanted as pine. In some cases where Norway and jack pine were transplanted, the average was over eight thousand trees a day for each man. Figures 33 to 42 illustrate the method used.

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[1] In forest terms, 1-0 means a seedling one year old, not transplanted; 2-0 means a two-year-old seedling not transplanted; while 2-1 means a seedling which grew two years in a seedbed and was then transplanted for a year before it was set out permanently. Likewise 1-2 means a seedling left in a seedbed one year and transplanted and left two years before being set out; 2-2, a young tree two years in a seedbed and two years in a transplant bed.

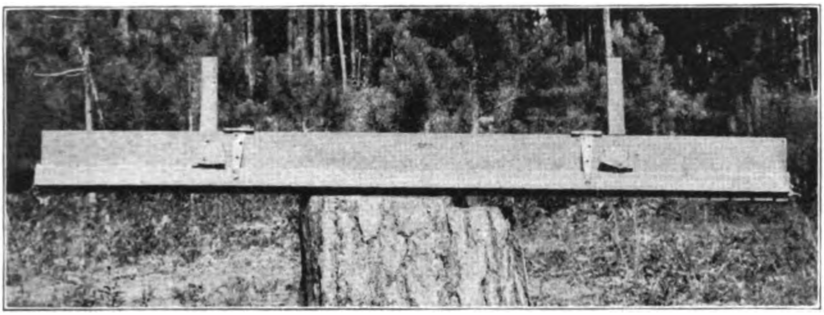

Fig. 33. Planting Board Used at Cloquet Station

This board has long rigid steel hinges which work better than the leather hinges formerly used.

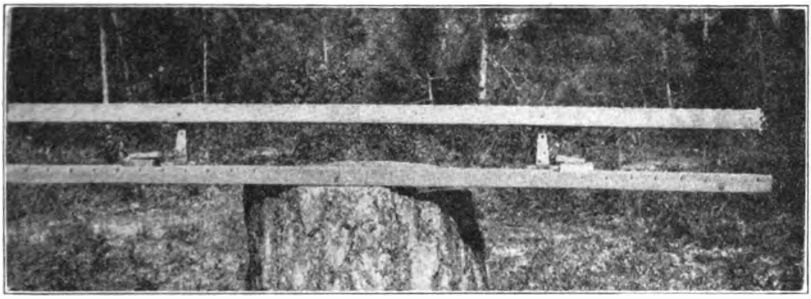

Fig. 34. Planting Board Open

Note the notches for the seedlings. The strip in which the notches are made is detachable, so that any spacing desired may be used, and any sized seedling accommodated. The upper clamp is covered with a strip of cloth to protect the tender bark of the seedlings.

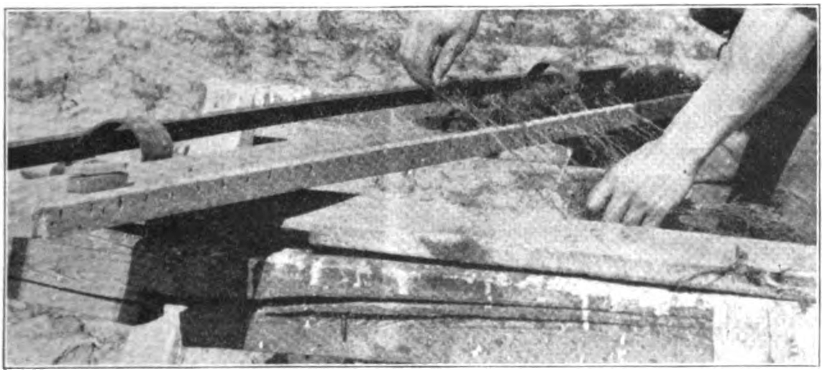

Fig. 35. Stringing or Threading Seedlings

In actual practice the boards are threaded in shelters, as shown in Figure 36.

In transplanting, each crew transplanted five boards on each side of the shelter, or ten boards in all. Each row contained 350 trees. For every row above 85 set by a crew in a day, a bonus of 5 cents a row was given to each man. This stimulated the laborers wonderfully.

The transplant stand[2].—The transplant stand shown in Figure 36 shades the seedlings while they are being threaded in the transplant board, and increases the rapidity of threading by its convenient arrangement for handling the board. In operating, the planting-board "c" is put by the planter on the shelf "h." The threader then lifts it to the position shown in the cut, with the clamp open. After placing the seedlings in the board, he closes the clamp and pushes the board, which slides down "e" and rests on the shelf "g," in readiness for the planter. It is possible for one man to thread 18,000 seedlings in a day by this method.

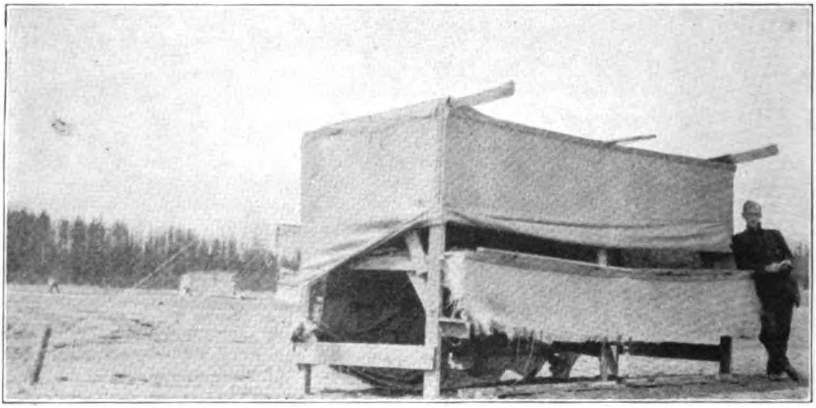

Fig. 36. Stand for Threading Transplant Boards

These stands are covered with canvas or burlap to protect the roots of the young trees from the wind and sun while they are being handled. Two threaders work inside of the stand threading the boards for two planters. A "trencher man" makes the trench into which the seedlings are transplanted by the planters.

Digging transplants.—Up to this time all transplants have been dug with potato forks. This is hard work and it is hoped that some way of using a plow or other machine for this work will be found.

The cost per thousand of handling transplants averaged about thirty-five cents for digging and about the same amount for packing material, hauling moss, and other items. It is proposed to experiment with a different kind of packing box and to eliminate the cost for

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[2] A transplant stand quite similar to this was originally designed at the Savanac nursery of the United States Forest Service in Montana.

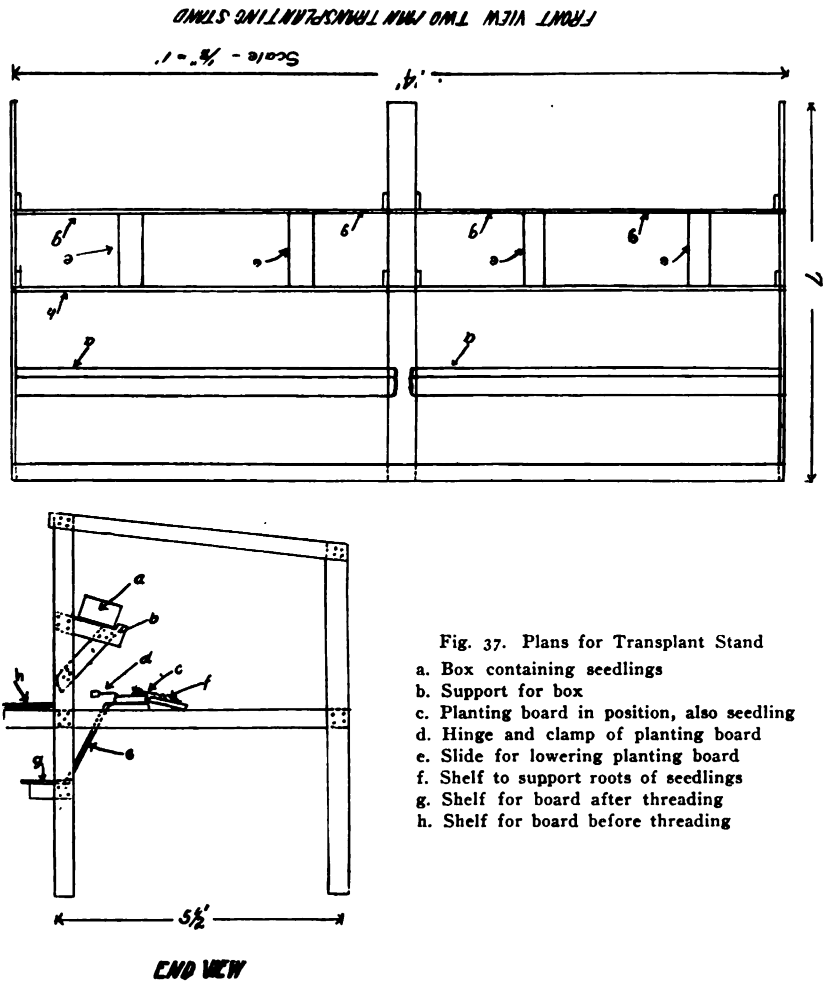

Fig. 37. Plans for Transplant Stand

a. Box containing seedlings
b. Support for box
c. Planting board in position, also seedling
d. Hinge and clamp of planting board
e. Slide for lowering planting board
f. Shelf to support roots of seedlings
g. Shelf for board after threading
h. Shelf for board before threading

hauling material. The cost per thousand of digging, packing, and hauling to Cloquet, based on an operation of 400,000 seedlings, was as follows:

Labor

	Per thousand	
Digging and putting into boxes	$0.34	
Packing (including getting moss, making new crates, hauling box shooks, repairing old boxes, finish packing, and loading)	0.08	
Hauling to Cloquet (four miles)	0.07	
Supervision	0.145	
Total labor		$0.635

		Per thousand
Material		
Box shooks (approximately 2/3 crate used)	$0.05	
Box-binding wire	0.01	
Total material		$0.06
Total cost		$0.695

The average number of seedlings dug and packed per man per day was 5,795.

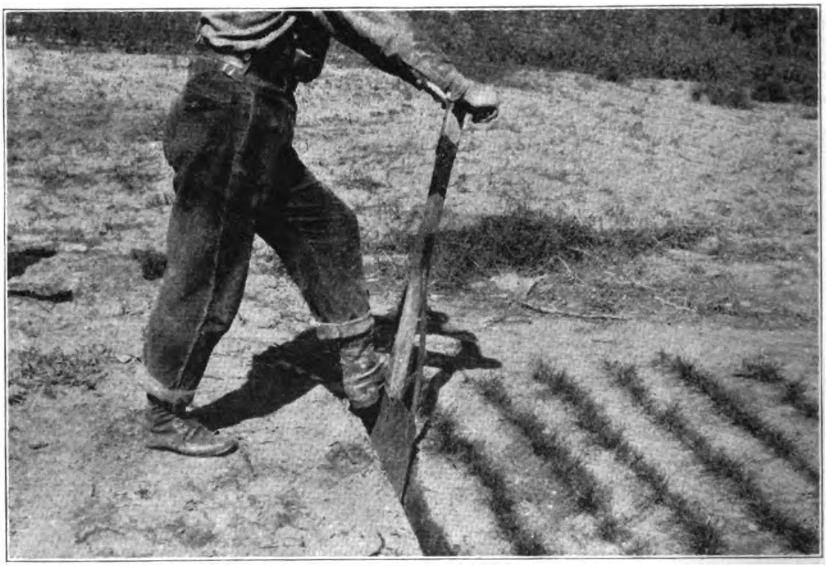

Fig. 38. Making the Trench

The trencher is a piece of sheet iron ⅛ inch thick, 2 feet long and 1 foot wide. If the ground is plowed, one man can easily keep two planters busy with this tool.

FOREST PLANTING

Very little study had been made in the Lake states of the suitability of the different species for planting on different types of land up to the time this Experiment Station was established. One of the principal studies at the Cloquet Station has been reforestation, the object being to fix a standard for determining the types of soil in the Lake region. After these types were determined, the next problem was that of determining the class of stock and the methods of planting which would give the best results.

The stock used in this experiment was 2-0 and 3-0 seedlings and 2-1, 1-2, and 2-2 transplants. The costs of these classes of stock vary considerably, and where the cheaper stock will give comparatively as good results, of course it is advisable to use it. Therefore very exten-

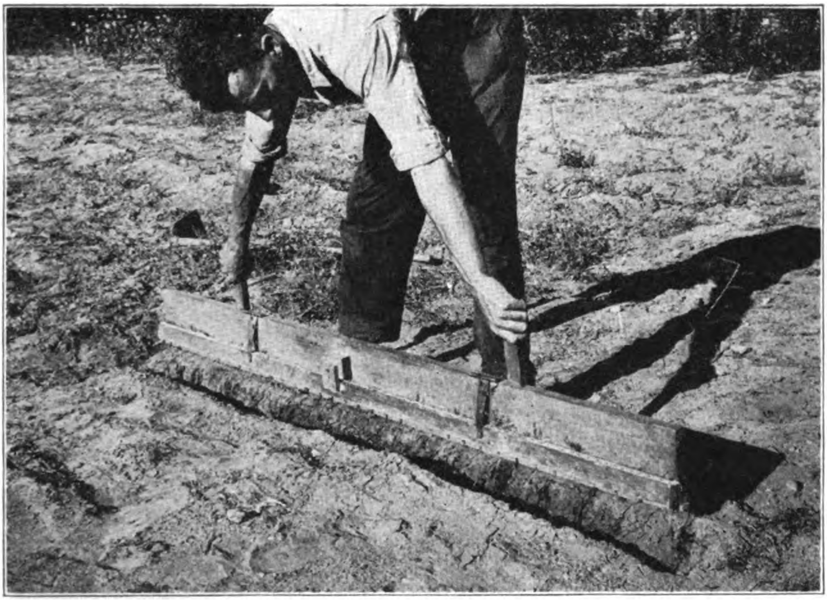

Fig. 39. Dropping the Roots of Seedlings Into Trench
This is the first operation with the planting board.

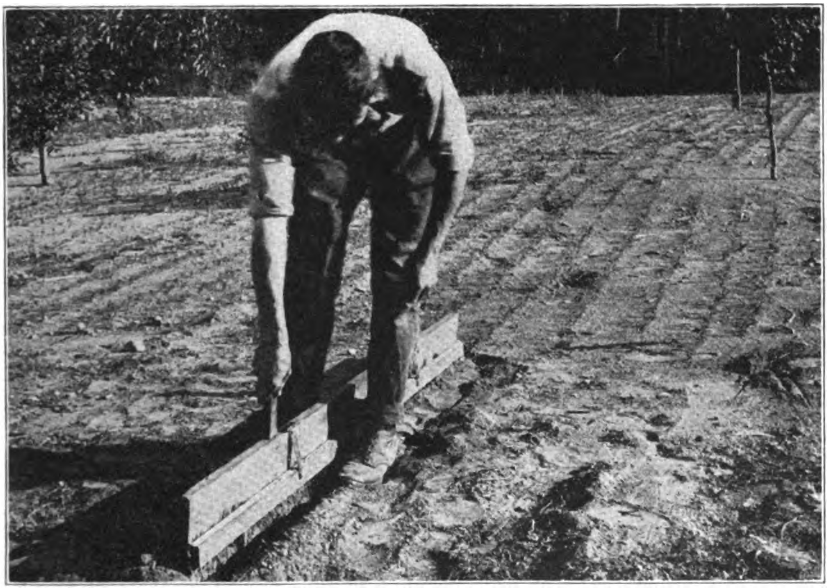

Fig. 40. Firming and Pressing the Soil Around the Roots
The soil is pushed into the trench and pressed around the roots by shuffling along the trench with one foot on each side of the planting board. The board keeps the tops straight and prevents the soil from covering the trees too deeply.

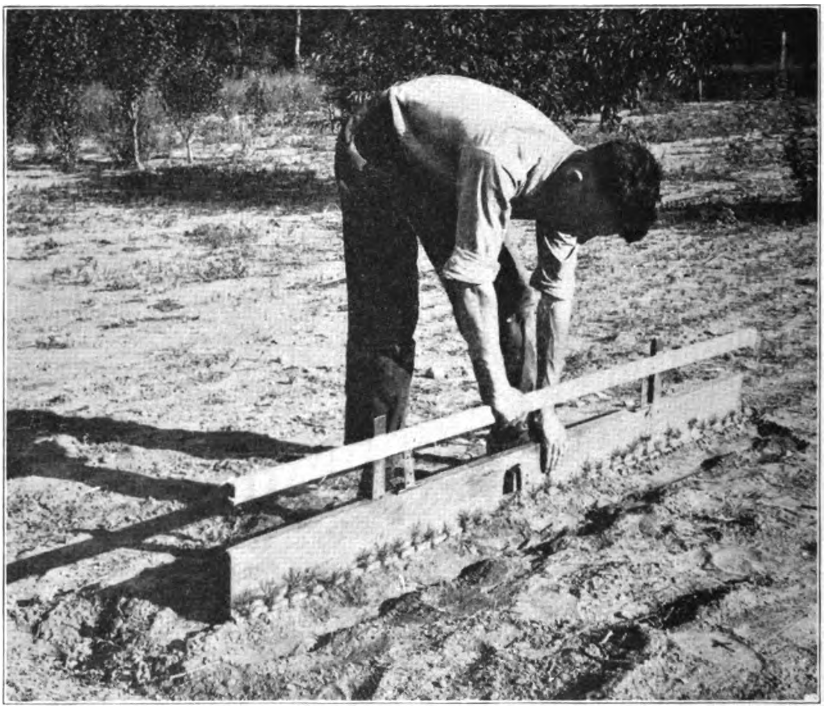

Fig. 41. Removing the Board
After the soil has been filled in around the trees the top clamp is loosened.

sive experiments have been conducted. The plots, which were laid out in the already determined types and situations, covered half an acre in nearly every case. In each of these plots, 500 trees were planted. The experiment was duplicated the following year and in some cases triplicated. The average results are quite conclusive.

METHODS

Another subject which has been investigated is the proper methods of planting to get the stock in most cheaply and at the same time secure a maximum survival. A local blacksmith was given plans for planting tools. (See Figure 45.) In the soils typical of the Lake states, such as sandy jack pine lands, these tools have given much better results than the old-time mattock. It has been possible to average 1,200 trees per man per day on some of the larger plantings, and some of these areas, after four years, have a stand of over 90 per cent. The results with the different classes of stock can best be understood from Table X.

Each plot contains 500 trees. They have been counted the two years following planting, in early spring and in the fall.

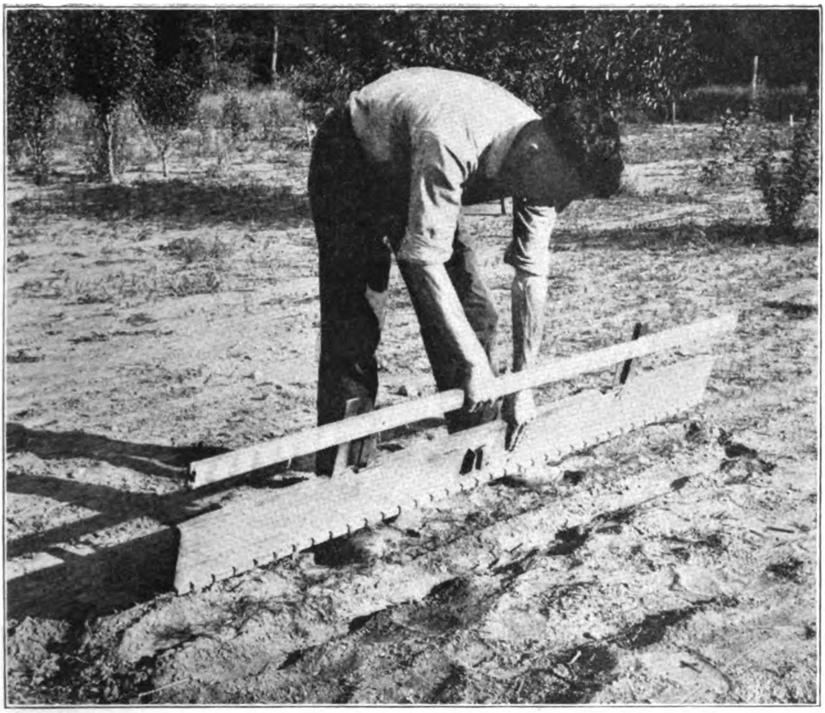

Fig. 42. Removing the Board

The board is now bent forward to release the tops from the notches and is carried back to the threading stand to be filled.

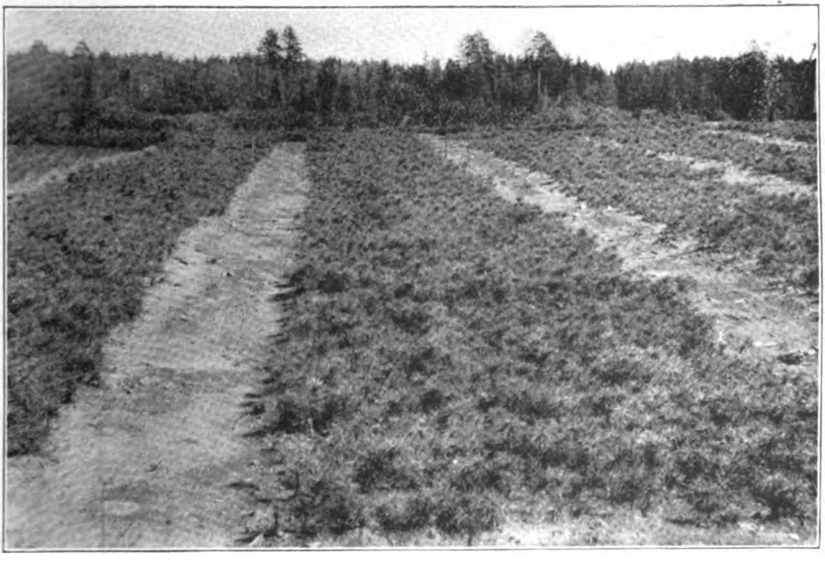

Fig. 43. White Pine 2-1 Transplants

Transplanting seedlings into beds six feet wide makes them very easy to weed.

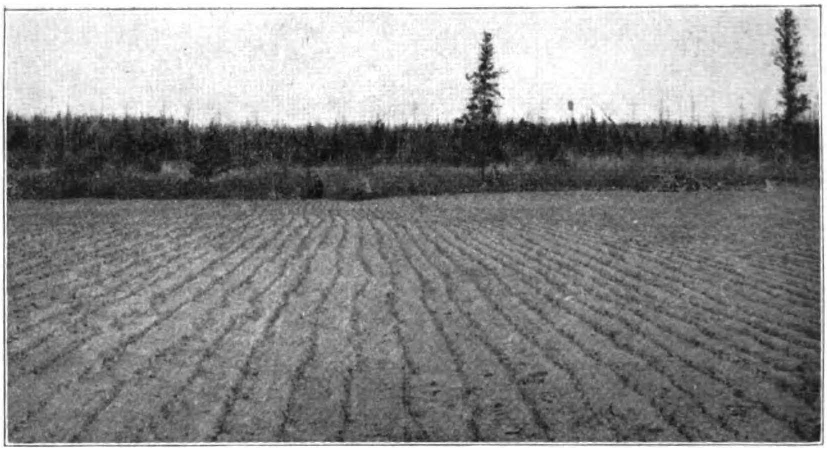

Fig. 44. Norway Pine Soon After Transplanting

Seedlings are not planted in beds when a plow digger is to be used to dig them. There are six acres of transplants in this field.

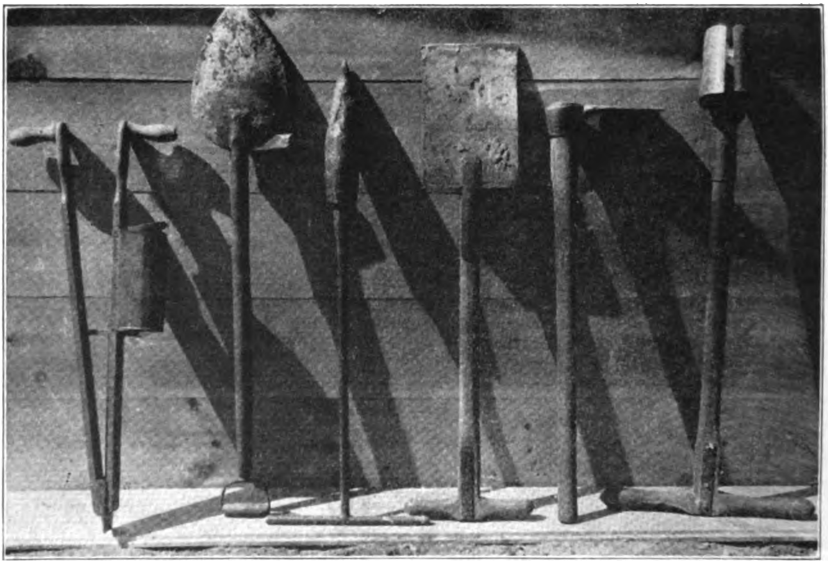

Fig. 45. Tools for Forest Planting

1. Corn planter used in one method of seed-spotting
2. Heart-shaped spade
3. Iron wedge (this was improperly made)
4. Wedge spade
5. Mattock or grub hoe used in planting and seed-spotting
6. Cylindrical spade used for planting and for digging forest-pulled stock

For the success of the above tools in the different situations, and for conclusions as to their practicability, see Table X.

The methods which have been employed for planting stock are classified under the tools used and the methods practiced, such as the wedge spade, heart spade, cylindrical spade, iron wedge, side-hole mattock, and center-hole mattock. The results are summarized in Table X. This table shows quite conclusively that the implement used and the method followed in planting, in many cases makes over one hundred per cent difference in the cost of the operation. The center-hole mattock method, for instance, while giving good results, is not cheap in the long run. Some of the other methods cost less than half as much.

TABLE X

SUMMARY OF METHODS AND COSTS OF PLANTING

		Situation	Wedge spade	Heart spade	Cylindrical spade	Iron wedge	Mattock, side hole	Mattock, center hole
Actual time required by two men to plant 500 trees—hours, minutes.		Open cut-over...	3:30	2:00	3:30	3:45	3:15	5:45
		Gravel knolls...	2:30	2:55	3:45	3:45	3:20	5:00
		Under 8-in. jack	2:20	2:15	3:30	3:00	2:15	4:30
		Thick brush....	4:10	2:20	5:50	6:05	5:00	7:55
Cost of planting only, 1,000 trees, or one acre, by two men at 20 cents an hour.		Open cut-over...	$2.80	$1.60	$2.80	$3.00	$2.60	$4.60
		Gravel knolls...	2.00	2.34	3.00	3.00	2.66	4.00
		Under 8-in. jack	1.86	1.80	2.80	2.40	1.80	3.60
		Thick brush....	3.34	2.66	4.66	5.66	4.00	6.34
Av. cost of each tool		All	$2.50	$2.10	$3.32	$3.52	$2.77	$4.64
			Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
First year	Percentage alive one month after planting.	Open cut-over...	89	87	90	92	53	84
		Gravel knolls...	91	97	95	91	92	80
		Under 8-in. jack	99	92	96	94	90	93
		Thick brush....	90	76	93	79	65	84
	Percentage alive at end of season.	Open cut-over...	85	75	83	83	53	82
		Gravel knolls...	69	87	87	74	85	77
		Under 8-in. jack	94	84	90	77	78½	96
		Thick brush....	58	34	31	6	17	38
Second year	Percentage alive at beginning of season.	Open cut-over...	86	76	..	82	49	80
		Gravel knolls...	77	87	86	76	85	69
		Under 8-in. jack	76	80	92	64	70	95
		Thick brush....	54	21½	24½	3	12	29
	Percentage alive at end of season.	Open cut-over...	85	72	77	82	39	85
		Gravel knolls...	70	87	86	74	82	64
		Under 8-in. jack	76	83	76	64	76	89
		Thick brush....	48	15	22	4	7	26

CLASSES OF STOCK

The most extensive experiment carried on at the Cloquet Station is to determine the classes of stock best suited to different situations. There are 360 half-acre plots, each containing 500 trees, planted in various situations, with the five classes of stock used. Each plot is staked to aid in checking.

Each class of stock is planted in each situation for three years in succession, 500 trees to a plot, so that the average condition of weather, stock diseases, and planting may be noted. The results obtained to date show that it is the height of folly to base conclusions on the results of one year. A particularly good year may give splendid results with a certain class of stock, whereas in a poor year the same class of stock may be a failure in the same situation.

Tables XI, XII, and XIII show the results obtained to date on this experiment.

Another study conducted is to determine the species and class of stock of spruce best suited for planting on cut-over swamps and low, moist spruce and hardwood bottoms. The results so far are not entirely conclusive, but give a very good indication of what may be expected. The results are given in Table XV.

The stock of red spruce was of very good grade and has made good growth, especially in the cut-over white pine and hardwood lands. The 2-1 stock made excellent growth. In the cut-over swamps of spruce and tamarack, the trees which have succeeded are in excellent condition and have made very good growth. It seems altogether probable that this species, if planted with 2-1 or 2-2 stock in the cut-over swamps, will be a success. Its success is almost assured in the cut-over hardwood land.

At the end of the second season the 2-1 stock of blue spruce has made only fair growth in the cut-over white pine and hardwood land, and has also made a fairly good growth in the cut-over swamps of tamarack and spruce. The 2-1 stock planted in 1915 was in good condition at the end of the season. It is probable that experiments will result in the determination of some class of stock that will be a success.

In the cut-over white pine and hardwood type, the land is quite low and moist and has a cover of balsam and maple, with black spruce, birch, and other brush. The white spruce stock used was very poor. It was obtained from a commercial nursery and was badly heated when received. It was also quite small. This experiment shows that it is inadvisable to plant 2-0 stock of this species in either of the situations, but from the fact that the stock was making good growth at the end of the season it is probable that a better class of stock will succeed on the cut-over region and probably in the cut-over swamps.

The Norway spruce stock was in very poor condition when planted. It was purchased from a nursery, and the mulch had not been properly removed from the young seedlings, consequently they were badly twisted and deformed. It seems probable that this species will show better results when better grades of stock are planted. This will be determined by experiments now being conducted.

TABLE XI

Results with Five Kinds of Planting Stock on Typical Sites; Percentage of Trees Alive One and Two Years After Planting

Site	Stock	White pine		Norway pine		Jack pine		Scotch pine		Western yellow pine	
		Per cent alive		Per cent alive		Per cent alive		Per cent alive		Per cent alive	
		1st year	2d year	1st year	2d year	1st year	2d year	1st year	2d year	1st year	2d year
(1) Barren areas with little cover	2–0	80	77	73	67	77	66	84	72	93	..
	3–0	85*	83*	70	70	..	..	..	..	..	..
	2–1	86	81	80	78	96	..	..	..	..	..
	1–2	92	81*	95*	..	..	..	91*	..	44*	42*
	2–2	95	95*	95	91*	..	..	94*	..	..	..
(2) Cut-over areas grown up to sweet fern	2–0	82	72	82	71	70	61	81	74	72*	..
	3–0	74*	61*	72	66	..	..	..	..	..	..
	2–1	90	88	79	69	94*	..	97*	..	..	..
	1–2	92	76*	89*	..	..	..	..	..	77*	56*
	2–2	91	81*	99	87*	..	..	86*	..	..	..
(3) Areas covered with thick brush	2–0	69	64	72	50	78	62	83	56	76*	..
	3–0	69*	58*	73	70	..	..	..	..	..	..
	2–1	67	66	55	45	90*	..	89*	..	..	..
	1–2	82	52*	79*	..	..	..	97*	..	83*	72*
	2–2	85	73*	96	84	..	..	..	..	..	..
(4) Sandy soil with scattered jack pine	2–0	70	67	67	63	90	..	88	..	..	..
	3–0	69	68	78	77*	..	..	..	..	79*	..
	2–1	92	89	66	65	100*	..	91*	..	..	..
	1–2	93	90	97*	..	..	..	95*	..	84*	74*
	2–2	94	..	98	..	..	..	..	..	..	..

* Results of one trial. All others are the average of duplicate plots planted two or more consecutive years.

TABLE XII

Average Percentage Alive of Each Class of Stock in All Situations*

Stock	Year	Time of count	White pine		Norway pine		W. Yellow pine		Jack pine		Scotch pine	
			Trial one	Trial two	Trial one	Trial two	Trial one	Trial two	Trial one	Trial two	Trial one	Trial two
2–0	First	Spring	72	98	71	98	96	..	85	94	89	94
		Fall	58	92	59	92	80	..	68	90	79	89
	Second	Spring	58	88	49	85	..	..	66	..	74	..
		Fall	57	85	47	79	..	..	63	..	67	..
2–1	First	Spring	83	98	76	98	..	..	98	..	98	..
		Fall	72	95	58	85	..	..	95	..	92	..
	Second	Spring	71	92	57	71	..	..	..	..	..	..
		Fall	70	92	56	67	..	..	..	..	..	..
1–2	First	Spring	90	99	99	..	79	..	..	..	98	..
		Fall	84	96	90	..	72	..	..	..	93	..
	Second	Spring	77	..	..	..	64	..	..	..	..	..
		Fall	75	..	..	..	61	..	..	..	..	..
3–0	First	Spring	79	..	95	80	..	..	..	..	..	..
		Fall	74	..	82	65	..	..	..	..	..	..
	Second	Spring	70	..	81	..	..	..	..	..	..	..
		Fall	68	..	73	..	..	..	..	..	..	..
2–2	First	Spring	97	98	99.6	100	..	..	..	..	..	..
		Fall	92	90	98	96	..	..	..	..	..	..
	Second	Spring	86	..	91	..	..	..	..	..	..	..
		Fall	83	..	87	..	..	..	..	..	..	..

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* Trial 1 represents the first planting and Trial 2, the repetition of Trial 1 in the same situations and with the same class of stock, when available.

TABLE XIII

SUMMARY OF FOREST PLANTING;* PERCENTAGE ALIVE IN TYPICAL JACK PINE SITUATIONS

			White pine						Norway pine						Scotch pine						Western yellow pine					
Stock	Year	Time of count	Young dense jack pine		Medium sized jack pine		Mature scattered jack pine		Young dense jack pine		Medium sized jack pine		Mature scattered jack pine		Young dense jack pine		Medium sized jack pine		Mature scattered jack pine		Young dense jack pine		Medium sized jack pine		Mature scattered jack pine	
			Tr. 1	Tr. 2	Tr. 1	Tr. 2	Tr. 1	Tr. 2	Tr. 1	Tr. 2	Tr. 1	Tr. 2	Tr. 1	Tr. 2	Tr. 1	Tr. 2	Tr. 1	Tr. 2	Tr. 1	Tr. 2	Tr. 1	Tr. 2	Tr. 1	Tr. 2	Tr. 1	Tr. 2
2–0	First	Spring	77	..	76	..	94	..	63	..	72	..	51	..	95	100	97	99	96	98	94	..	100	..	99	..
		Fall	57	..	61	..	90	..	63	..	58	..	28	..	86	95	93	93	87	95	60	..	84	..	94	..
	Second	Spring	53	..	64	..	87	..	66	..	..	..	..	..	88	..	96	..	86	..	..	..	..	..	..	..
		Fall	52	..	58	..	85	..	37	..	41	..	..	..	83	..	92	..	97	..	..	..	..	..	..	..
2–1	First	Spring	87	96	71	98	90	96	85	89	81	95	96	92	100	..	..	..	..	..	..	..	..	..	..	..
		Fall	81	81	62	97	85	93	31	69	69	93	87	81	95	..	..	..	..	..	..	..	..	..	..	..
	Second	Spring	86	..	57	..	82	..	14	..	65	..	81	..	..	..	..	..	..	..	..	..	..	..	..	..
		Fall	75	..	57	..	81	..	15	..	57	..	79	..	..	..	..	..	..	..	..	..	..	..	..	..
1–2	First	Spring	100	..	100	..	100	..	98	..	100	..	99	..	98	..	..	..	100	..	..	..	..	..	..	..
		Fall	100	..	100	..	100	..	96	..	99	..	100	..	96	..	..	..	93	..	..	..	..	..	..	..
	Second	Spring	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
		Fall	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
3–0	First	Spring	89	..	80	..	91	..	..	67	93	81	79	83	..	..	..	..	..	..	..	..	..	..	..	..
		Fall	80	..	79	..	84	..	89	73	89	75	67	70	..	..	..	..	..	..	..	..	..	..	..	..
	Second	Spring	68	..	72	..	83	..	73	..	84	..	87	..	..	..	..	..	..	..	..	..	..	..	..	..
		Fall	68	..	71	..	82	..	89	..	88	..	75	..	..	..	..	..	..	..	..	..	..	..	..	..
2–2	First	Spring	96	100	99	100	95	100	100	100	99	100	100	98	..	..	..	..	..	..	..	..	..	..	..	..
		Fall	95	99	96	97	90	95	98	97	98	98	98	99	..	..	..	..	..	..	..	..	..	..	..	..
	Second	Spring	85	..	†94	..	92	..	97	..	97	..	90	..	..	..	..	..	..	..	..	..	..	..	..	..
		Fall	†87	..	96	..	91	..	96	..	94	..	84	..	..	..	..	..	..	..	..	..	..	..	..	..

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* The first trial plantings were not all made the same year. The results of plantings in 1915 and 1916 were generally better than those of 1914 regardless of class of stock or situation.

† The increase in the percentage alive in fall over the percentage alive in the spring is due to the fact that a few of the trees which appeared to be dead in the spring recovered and looked thrifty in the fall.

TABLE XIV

Summary of Results with Forest-Pulled Stock in Three Situations

		Cut-over areas				Under 7-inch jack pine				Thick brush areas			
		White pine		Norway pine		White pine		Norway pine		White pine		Norway pine	
		1914	1915	1914	1915	1914	1915	1914	1915	1914	1915	1914	1915
		Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Percentage of trees alive the first year	Spring	64	78	73	98	66	99	93	95	70	84	91	96
	Fall	61	66	57	57	70	94	80	95	59	60	43	88
Percentage of trees alive the second year	Spring	57	....	52	....	62	....	75	....	41	....	35	....
	Fall	57	....	42	....	45	....	75	....	40	....	30	....

TABLE XV

Class of Nursery Stock of Different Species Best Suited to Planting on Types of Land Adapted to Spruce

	Cut-over white pine and hardwood								Cut-over swamp-spruce and tamarack							
Species of spruce........	Red		Blue		White		Norway		Red		Blue		White		Norway	
Class of stock...........	2–0	2–1	2–0	2–1	2–0	2–1	2–0	2–1	2–0	2–1	2–0	2–1	2–0	2–1	2–0	2–1
Percentage alive at end of first season	71	96	25	67	25	..	48	..	77	80	17	..	13	..	34	..
Percentage alive at end of second season	63	..	18	..	18	..	37	..	18	..	16	..	..	..	33	..

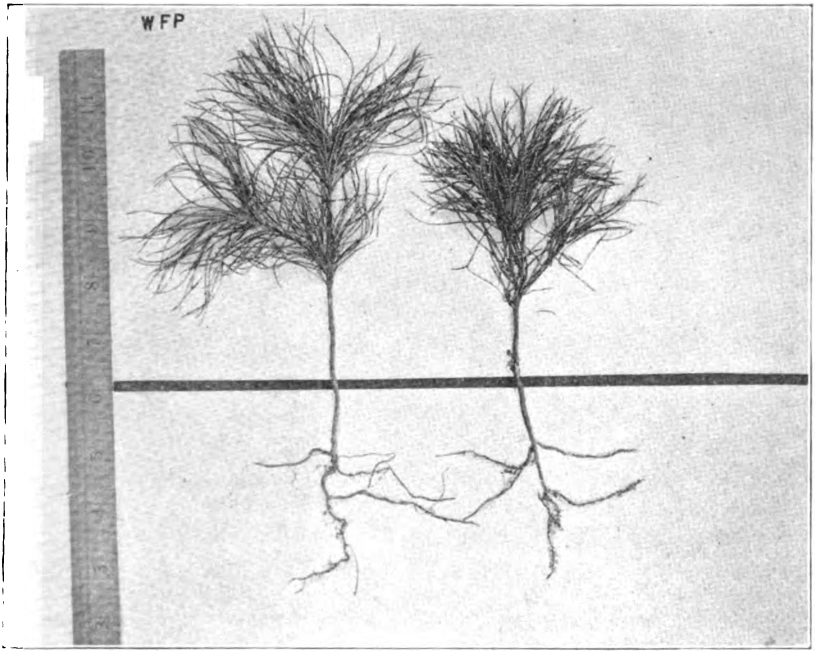

Fig. 46. Forest-pulled White Pine

This is a cheap kind of stock which is very easy to plant and which has moderate success in the different situations.

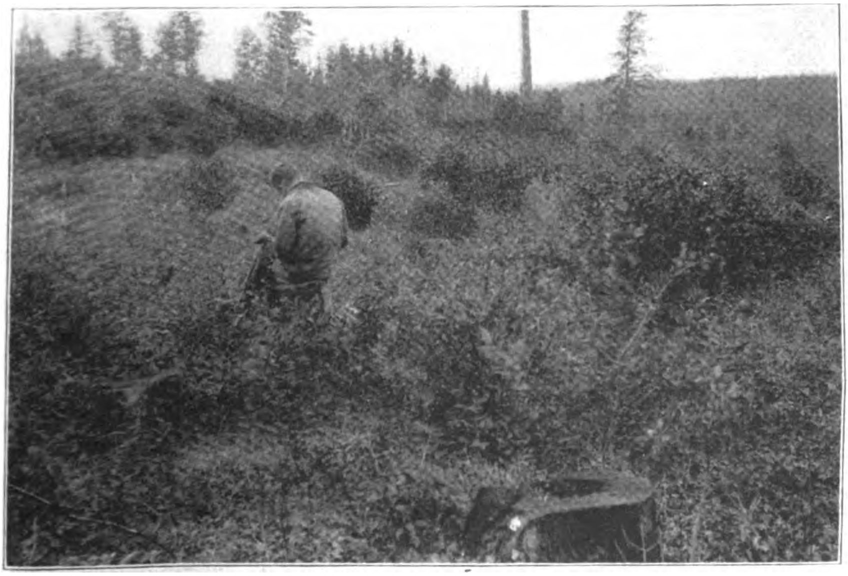

Fig. 47. Cut-over Land on which the Forest-pulled Stock Was Planted

The soil is a sandy clay. The ground cover is strawberry, blueberry, bunch grass, and cat's-paw. The following are coming in: Alder, hazel, willow, poplar, honeysuckle, and red cherry, with some reproduction of Norway pine.

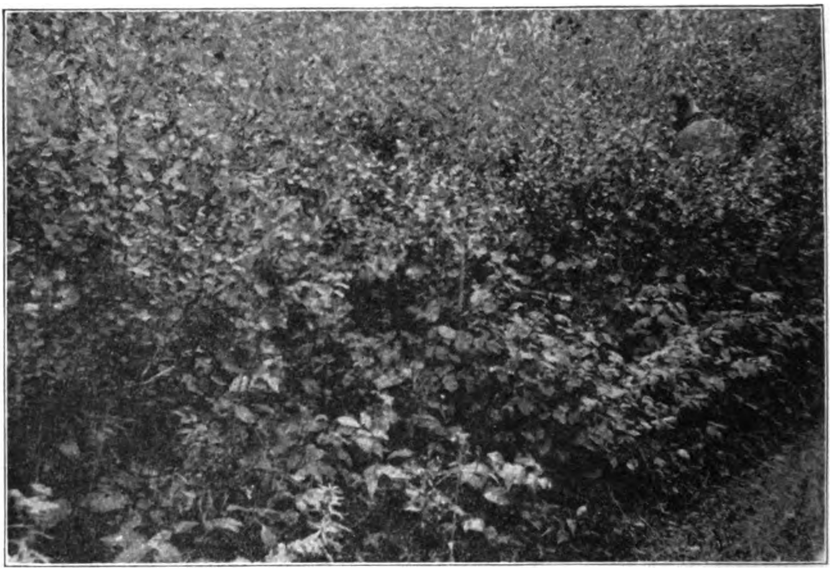

Fig. 48. Site 3, of Planting Project (Table XI)

The purely herbaceous growth consists of bracken fern, wild sarsaparilla, and bunch grasses. The brush includes alder to 10 feet in height. Poplar to 20 feet in height is predominant, with a mixture of willow, hazel, and cherry. The permanent type was white and Norway pine on a sandy clay top-soil and with a sub-soil of gravel. This is typical of all situations used for Site 3.

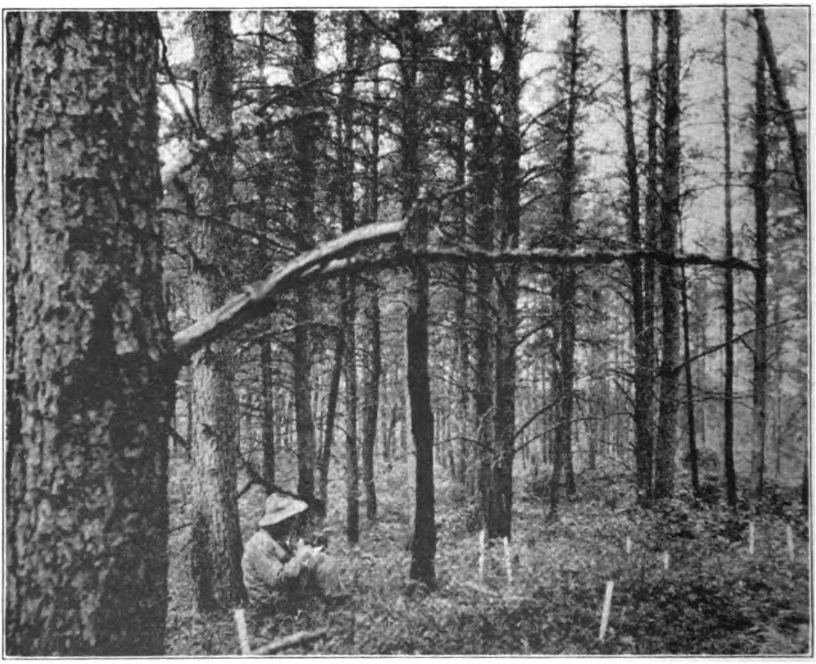

Fig. 49. Site 4, of Jack Pine Situation (Table XI)

The ground cover is thick and consists largely of wintergreen, arbutus, blueberry, and strawberry, with scattered bracken fern and dogbane. The brush, which is very light, consists of willow, hazel, alder, and Diervilla sp. The soil is very typically jack pine sand with a present stand of jack pine from 6 to 10 inches in diameter.

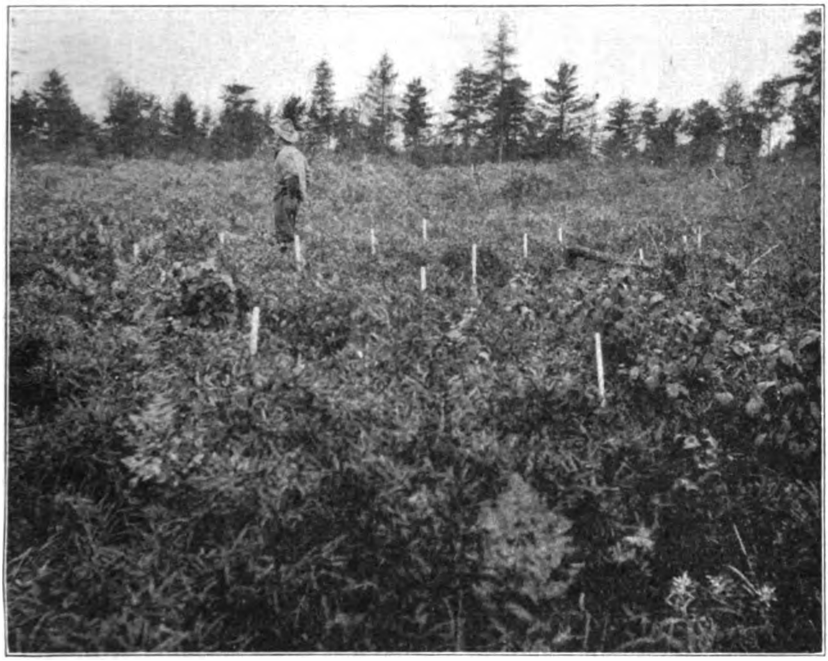

Fig. 50. Site 2, Cut-over Sweet Fern Area (Table XI)
Besides the dense cover of sweet fern, the following kinds of brush are found: Poplar 2 to 4 feet high, willow, hazel, and blueberry. All of these are scattered.

SEED-SPOTTING

In a favorable year, when there is enough moisture uniformly distributed so that the young seedling does not dry out in the first weeks following germination, seed-spotting has been quite successful. At first the spots were made with a heavy hoe. A spot was cleared and about ten seeds were sown in it. These generally germinated fairly well but as the young seedlings had no cover, many of them died. Later, spots were made by cutting the duff and sod finely but leaving it as a mulch. The seed were dropped on the finely pulverized top soil of this spot, covered lightly, and pressed down with the foot.

The objection to seed-spotting in this part of the state is that it takes nearly as much time to make seed spots properly and to thin out the seedlings as it would to plant young trees in the spots; but in the rocky northeastern part of the state, where planting is difficult owing to the scarcity of soil, this method is worth trying.

We have had no trouble with rodents taking the seed from the spots. In some cases the white pine seed were three years in germinating and for a time the rodents were accused of taking them. In some cases the spots contained seedlings from 1 to 4 years old.

Table XVI gives the results in some of the plots that were seed-spotted.

TABLE XVI
SEED SPOTTING ON DIFFERENT TYPES OF FOREST LAND

	Jack pine			Sweet fern			Open cut-over		
	Norway pine	Scotch pine	White pine	Norway pine	Scotch pine	White pine	Norway pine	Scotch pine	White pine
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Fall sowing:									
Alive at end of 1 year*	85	55	11	..	..	..	40	7	17
Alive 2 years after sowing......	77	49	19	..	..	..	..	17	..
Alive 3 years after sowing.......	68	46	11	..	..	..	..	15	24
Spring sowing:									
1912—									
Alive 1 year after sowing......	25	80	85	7	47	41	2	81	51
Alive 2 years after sowing......	22	65	85	..	46	34	..	85	43
Alive 3 years after sowing....	18	..	..	..	..	..	..	..	..
1913—									
Alive 1 year after sowing......	68	..	..	69	..	..	60	..	..
Alive 2 years after sowing....	58	..	..	56	..	..	41	..	..

* Percentage alive refers to number of seed spots with living seedlings.

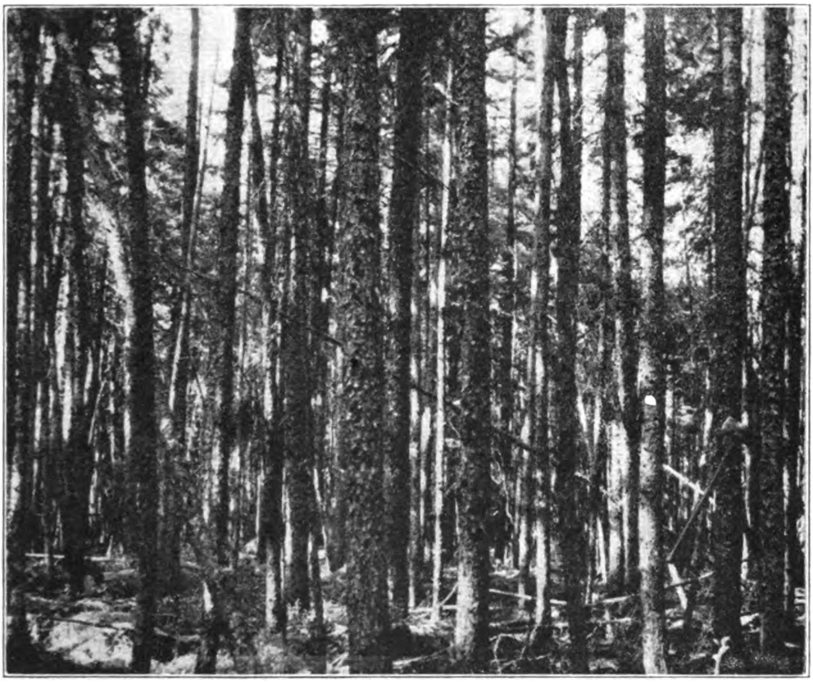

Fig. 51. Nearly Pure Type of Black Spruce

There are approximately twenty-five acres in the forest. The stand averages five and one half inches in diameter, breast high, and is about one hundred years old. It will yield approximately forty cords per acre in four-foot lengths.

In situations where there is enough cover to prevent the seedlings from drying out the first few weeks after germination, and brush is not thick enough to cover the young seedlings with leaves, experiments with Norway pine have been very successful. The same objection which holds true with all species, namely, the thick stands in some of the spots, is very evident in this experiment. The best situations for seed-spotting are jack pine stands, when the object is to secure a stand of Norway pine which will eventually replace the jack. The seedlings, except where too much shaded, were in good, healthy condition at the end of the third year.

Scotch pine seed in some places came up the year following sowing, but in no case was there any evidence that it remained viable for more than one year. Scotch pine succeeded better than either Norway or white pine in the open, exposed areas where all three were sown under identical conditions. Most of the Scotch pine seedlings are making very good growth and most of the losses are due to hardwood leaves burying the young seedlings.

A great many white pine seedlings came up the second year, but in some cases the seed remained over until the third year. All the seedlings whose young roots were protected from drying out until they were able to penetrate deep enough to get sufficient moisture to withstand dry conditions, have succeeded. At the end of the third year the seedlings were in good condition. The objection to this method of planting is that in many plots the seedlings were too thick to insure good development and were in need of thinning. The greatest factor responsible for the loss of seedlings in seedspots is hardwood leaves. When they fall to the ground they cover the seedlings and cause a very moist condition around the trees, so that damping-off is very prevalent. Where brush is not too thick and there is some overhead shade, like jack pine, seed spotting has been very successful.

SITES

The study of sites is concerned with the ecological conditions and factors determining the growth and development of the species native to this region.

The work so far has been limited to the jack pine, the Norway-white pine, and the swamp types of forest which prevail throughout most of northern Minnesota. The results have been tabulated for four years and consist of records of rainfall; snowfall; air temperature; wind velocity; soil temperatures at depths of 6, 12, and 24 inches; evaporation in the different types; and determinations of total soil moisture and moisture equivalent. The results from the moisture-equivalent determinations are being used as a standard for determining the types of soil particularly suited to certain species.

Evaporation studies have been carried on somewhat differently from those at any other station, the object being to determine the actual loss of water from a cubic foot of soil. It is a well-established fact that the evaporation from the top foot of soil is one of the determining factors in the success of stock that is in good condition when planted.

These results have been converted into inches of rainfall, so that an increase in the amount of moisture in the upper foot of soil is expressed as a gain of so many inches of rainfall, and a decrease as a loss.

In this way it is possible to determine the gain and loss and to compare the amount of water in the soil in one situation with that in any other situation.

In determining the evaporation, two zinc or brass boxes were used, the inner one holding exactly one cubic foot of soil. This soil was cut out in a solid block by first digging a trench and then driving thin pieces of sheet iron on three sides and on the bottom. The inner box was fitted very tightly into the outer one, which was put in the ground with the top flush with the surface. Both boxes were perforated on all four sides and the bottom, so that the soil inside was in direct contact with that outside. This prevented the circulation of air around the outside, which might cause the outer part of the soil in the box to dry out. Platform scales which weighed to within one fourth of an ounce, and up to two hundred pounds were located at each evaporation box. The inner boxes, containing a cubic foot of soil, were weighed twice a week. When the weather was dry, the boxes lost weight. The loss varied in different situations. For instance, the box in the nursery, which contains nursery soil with no needles or vegetative cover often lost five pounds in weight, while the box in the Norway-white pine type of soil, which was protected by a natural mulch of pine needles and shaded by mature trees, lost only about one pound. The increase in weight of these boxes was translated into inches of rainfall and the gain of these various types could be compared in that way. To illustrate, a cubic foot of water weighs about 60.5 pounds. If one of the boxes showed an increase of 5.04 pounds, this meant that the upper foot in this type of soil had received and retained one inch of rain. Correspondingly, if subsequent weighing showed that the box was 10.08 pounds lighter than at a previous weighing, two inches of rainfall had been lost by this upper foot of soil.

These data showed some very interesting differences between different types.

About three hundred moisture-equivalent determinations were made by the Division of Soils, of the Agricultural Experiment Station at University Farm, St. Paul. These determinations have established a good standard for the types of soil to which jack pine, white pine, Norway pine, white spruce, poplar, and balsam fir are adapted. The method and use of this standard are explained in an article by the writer in the Proceedings of the Society of American Foresters.[3]

EXOTICS

Some exotic trees were obtained from the Bureau of Foreign Seed and Plant Introduction in 1913. Nearly all of them have grown and some of them, excellently. Results are summarized as follows:

Plants No. 30057, *Populus alba bolleana,* were received April 7, 1913, from Yarrow. These were planted May 1, in the nursery. They grew very well and by October had made an average growth of over three feet.

---

[3] **Kenety, W. H.** Use of meteorological studies in management and reforestation studies. Proc. Soc. Am. For. Vol. 10, No. 3, pp. 266-271. 1915.

Plants No. 30147, *Populus nigra,* were planted at the same time and made a good growth during the summer, but the tops were frost-bitten early in the fall.

Plants No. 33120, *Fraxinus ornus,* were received April 7 and planted May 2. They grew fairly well.

Plants No. 22861, *Populus sp.,* grew fairly well but their tops were damaged by early frost.

Plants No. 26614, *Populus beroliensis rossica,* grew excellently and at the end of the growing season were nearly five feet high. These came from Chico.

Plants No. 22975, *Ulmus pumila,* were received April 7 and planted May 2. They made a good growth.

Plants No. 22447, *Populus balsamifera suaveolens,* made a fair growth.

Plants No. 22418, *Salix babylonica,* made a fair growth.

A large number of other trees have been procured this year from the same source and it is hoped that some of them can be adapted to this region. The *Populus beroliensis rossica* has done wonderfully well on the sandy soil of northern Minnesota. Last year about two hundred cuttings were made from the six original trees and all have made a growth of several feet. This tree grows very rapidly and should make excellent windbreaks, as the branches are very thick.

SPECIES

In order to learn what species of conifers are adapted to the Lake states, arrangements were made with the United States Forest Service to furnish this Station with 125 transplants of each of sixteen different species. These species are not native to this climate but are probably suited to it. They are:

Scotch pine
Douglas fir
Norway spruce
Yellow pine
Western white pine
Engelmann spruce
Sitka spruce
Lodgepole pine
Western red cedar
White spruce
Noble fir
Amabilis fir
White fir

This study is necessary before any systematic introduction is attempted. In order that their growth and behavior might be compared, they were given the best care possible. They were set out in a cultivated part of the nursery where the soil is the best and where there would be no competition. One hundred were planted in each plot, six feet apart. The plots are situated near one of the main roads and are of interest to the public. The following species were planted in the fall of 1913:

Western white pine from the Lolo Nursery, Montana; grown from Idaho seed; 2-1 stock.

Norway spruce from the Wasatch Nursery, Utah; 2-1 stock; seed from Germany; trees transplanted in 1912.

Lodgepole pine from Uinta Nursery, Utah; seed from the Arapaho National Forest, Colorado; 2-0 stock; sown in the spring of 1911.

Scotch pine from the Nebraska Nursery at Halsey; 2-1 transplants.

Douglas fir from the Pike Nurseries, Monument, Colorado; 2-1 stock; transplanted in the spring of 1912.

Engelmann spruce from the Pike Nurseries; 2-1 stock; transplanted in the spring of 1912.

Noble fir, 2-1 stock, no record of origin.

The results of the plantings of the fall of 1913 may be roughly summarized as follows:

About ten per cent of the Scotch pine died. What was left has made excellent growth. Nearly one hundred per cent of the Douglas fir is alive but making a poor growth. About fifty per cent of the western white pine is alive, but making only a mediocre growth. Engelmann spruce is showing up in fine shape, nearly one hundred per cent growing. Lodgepole pine from home-grown seedlings is growing finely; that obtained from the Uinta Nursery is not growing very well. The Noble fir all died.

FOREST INFLUENCES

The only study that has been made of forest influences has been the effect of the different forest stands on the accumulation and melting of snow. Snow stakes were placed in the various forest types and readings taken once a week showing the depth of snow from week to week in each type from the first snow in the fall to the melting of the last in the spring.

One thing is particularly shown, that a windbreak around the nursery is very desirable, as it causes the snow that falls on the nursery beds to remain. It has suggested the desirability of running a row of windbreaks through the nursery at intervals of about 200 yards, so as to do away with all mulching in the winter.

MANAGEMENT

SYSTEMS FOR SECURING REPRODUCTION

The seed-tree method for securing reproduction has been tried quite extensively at the Station. About fifty acres of Norway pine were cut over and two trees, on the average, left on each acre. These trees were selected because of their large crowns and other features which mark them as being desirable seed trees. An area of 80 acres was cut over and left to Norway and white pine in another region where the soil was heavier and was typical white pine soil. Plots were laid out in all parts of these areas which radiated in all directions from seed trees, and all seedlings within the plots were pulled up. Any seedlings that grew afterwards, with the exception of those from seed which may have laid over in the ground, would be derived from the seed trees. The results have been very disappointing. Very few seedlings have appeared, owing to a great many factors, the principal ones being rodents, which took most of the seed on the trees; and the heavier growth of brush which came in immediately after cutting and choked out the seedlings either by shading them too much or by covering them with fallen leaves, thus producing conditions very favorable for diseases. It was found that usually the seed trees did not distribute their seed much more than 100 feet in any direction. The system might be classed as almost a total failure, and from the results obtained we would very emphatically discourage the individual seed-tree system in northern Minnesota for either white or Norway pine. The value of the trees that were left would easily have paid the cost of planting the area.

METHOD OF CUTTING

In the spruce-tamarack type, the system of cutting has been used which took out all spruce over ten inches in diameter, breast high, and all small tamarack that would make stave bolts. It is almost too soon to draw any definite conclusions on this method of cutting for the swamp types typical of northern Minnesota, but in cases where the balsam is not too thick, results have been quite favorable. Where the balsam is very thick, the tendency in cutting out the other trees is to increase the chances for damage by wind, and balsam is very easily blown over. As there has been a big increase in the demand for balsam for both pulp and lath, quite intensive experiments are planned as to the best methods for securing natural reproduction of this species. The industries now started in northern Minnesota use this tree when quite small; and as it is a prolific seeder and grows very fast in many situations, efforts will be made to determine the best methods of cutting to secure good reproduction.

With Norway pine, the system which has proved by far the best is that of cutting clear in even-sized stands immediately following a good seed year. Logging stirs up the soil and allows the seed to get a good start. Under fairly well-stocked stands of Norway pine there is very little undergrowth and the seedlings start early and are not hindered by brush. Experiments have shown that almost full sunlight is necessary to a good natural reproduction of Norway pine. Where cuttings are carried on alongside a large area of Norway pine, reproduction has come in right up to the line of cutting, but inside of the area which has not been cut no young trees can be found. At one time a considerable strip was cut through the length of the Station, approximately three miles. Cutting started at the east end before the seed had ripened and fallen to the ground. As cutting progressed westward, during the latter part of August and the first part of September, the seed began to fall. Plots along this strip show very clearly the increase in reproduction from east to west. In many spaces in the western end of the Station, where the trees were felled either when the cones were open or after the seed had fallen out, reproduction is too thick to give the best results. This shows quite clearly that the reproduction which came in was, in a large measure, derived from

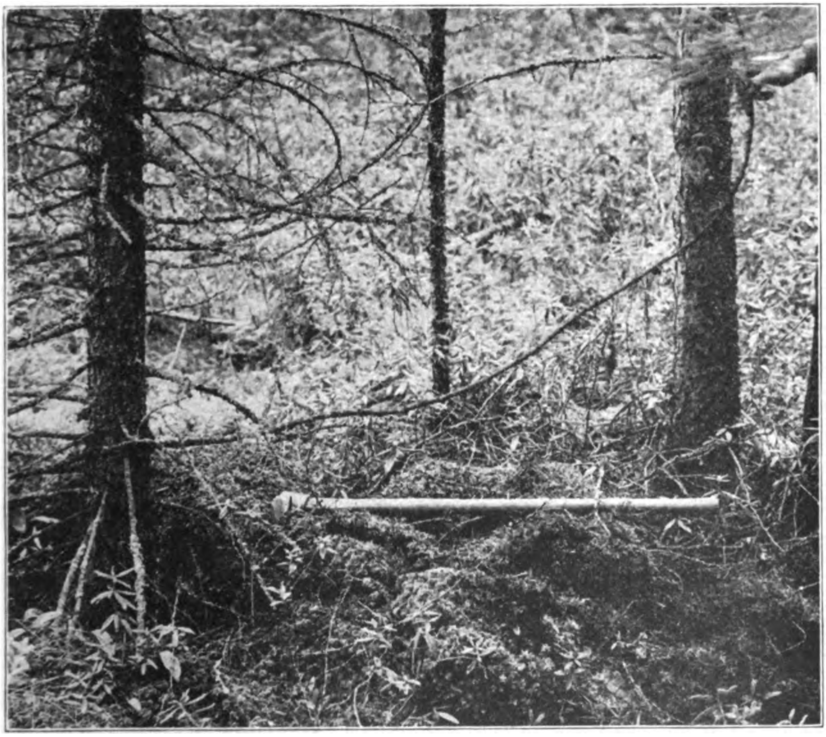

Fig. 52. Reproduction of Black Spruce

The moss and vegetative cover have been removed from this young tree, revealing the fact that it was a branch of the tree on the left. The branches above it are dead for many feet up. Note the adventitious roots on the branch. These roots will take up the task of supplying the young tree with food and ultimately the branch will decay and the tree will depend solely on its own roots for existence. As the young tree sends out branches the cycle will be repeated and in this way the black spruce will continue to possess the swamp.

best system to use with Norway pine. All bare places resulting can easily be stocked with forest-pulled seedlings that have come up too thickly.

NATURAL REPRODUCTION

Considerable work has been done on the reproduction of black spruce. The studies show that black spruce reproduces in the sphagnum swamps almost entirely from layering. Figures 52 and 53 illustrate this. Our experiments as yet do not prove conclusively that this method can be used artificially.

THINNINGS

Thinnings have been made in jack pine stands. In many cases jack pine has ten thousand trees to the acre. As a consequence very few of them have a chance to develop normally, and many of them become weak and spindling. Heavy snows break them down and make them very crooked. Experiments have been carried on in young stands of this nature and in stands which average about eight inches in diameter and have between six and seven hundred trees to the acre. In dense stands the young trees were culled out so as to leave

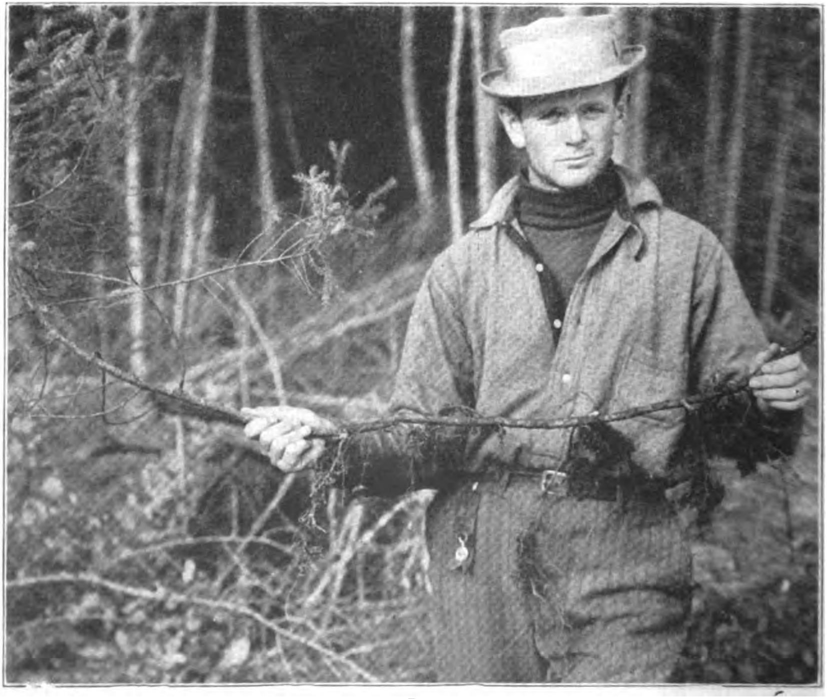

Fig. 53. Roots Developed on a Branch of Black Spruce by Layering

from one thousand to fifteen hundred trees to the acre. All trees that were left were tagged, and measurements were taken for height and diameter at a certain place. Check areas were selected, and in those areas trees of about the same size were measured and tagged. Next the seed of that year and not from any that had been stored up previously. This fact, that reproduction will follow the cutting immediately after a seed year, has been well illustrated twice from cuttings carried on at the Station, and it seems probable that this is the year, at the end of the five years, these trees will be measured and the increase in growth determined. The same thing was done with the larger stands of jack pine, altho in this case the crooked and poorly formed and suppressed trees were cut out. This reduced the stands to about five hundred trees to the acre. Check plots were laid out as in the young jack pine stands and all trees left were tagged, to be measured at five-year intervals. No thinnings have yet been made with any of the other species.

MENSURATION

GROWTH AND YIELD

Studies have been made of the growth and yield of white pine, Norway pine, jack pine, tamarack, poplar, balsam fir, and black spruce. On white pine and Norway pine, considerable information has already been obtained, but this will be added to as studies are carried on in different parts of the state, so as to obtain average conditions and average growth of these species on different soil types. Considerable work has been done with white spruce and poplar, and much information has accumulated on balsam fir. It is proposed to follow up the growth and yield of all of these species in typical regions in Minnesota.

SYLVICULTURAL STUDIES

DISTRIBUTION OF FOREST TREES AND TYPES IN THE LAKE REGION

As studies of other problems, such as mensuration and management, call for examinations of the various forest types in Minnesota, notes have been taken as to the distribution of the different trees and the density and development of these species. No attempt has been made to work out in definite form the exact range of any species.

FOREST TYPES

DESCRIPTION AND BASIS OF DETERMINATION

As a basis for determining forest types, we have inaugurated a system for classifying these types as to soil. As there are no altitudinal differences great enough to cause any change in types, and as the climatic conditions over the forest regions of northern Minnesota are almost uniform in precipitation and temperature, the factor which must be responsible for the difference in types is the soil.

Soil determines the amount of water which will be retained for forest growth, the temperature in which the roots will live, the acidity or alkalinity of the soil solution which they will take up, the aeration of the roots, and in fact nearly all of the variable factors which influence tree growth. It stands to reason that the thing which determines the permanent types in this region must be the soil, and if determinations are to be made of the forest types in this region, they must be based on the soil.

Various methods have been suggested for determinations of types based on soil, but the one which we have found to be the most usable as a basis for classification is the moisture equivalent of these different soil types. Studies were made of the soil in the best virgin stands to be found of these various types. The moisture equivalent determinations in these stands were taken as a standard for comparing all others which have been cut over, burned over, or occupied by some temporary type. These virgin stands had naturally shown their superiority over the other forest types for the particular type of soil on which they are dominant. It is natural to infer that in a like type of soil, under natural conditions, this same type of forest would ultimately take possession. The best method of comparing these types, as far as we have been able to find out, is the moisture equivalent method, and the more information secured and the more data accumulated from year to year, the more reliable does the standard become for the determination of these types. About four hundred soil determinations have been made by the Division of Soils of the Agricultural Experiment Station at University Farm, all of these being accurate samples from four or five borings and extending down five feet.

SPECIAL STUDIES

A coöperative agreement has been entered into with the Division of Plant Pathology and Botany for carrying on special studies in nursery diseases.

TREE STUDIES

The only species of which an individual study has been made is the white spruce, but a like study of jack pine is planned for next year.

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SUMMARY

1. Rotations carried out on University Farm, made up of grains, clover and timothy hay, and cultivated crops with moderate applications of manure, have maintained yields, and with one exception returned net incomes of $8.76 or more per acre. Pages 16 to 24.

2. Systems of cropping including grain only or grain and corn with moderate applications of manure, with no clover grown, did not maintain yields and the net income averaged $7.75 per acre, or 11.53 per cent lower than for the better class of rotations, those made up of the three classes of crops, grain, clover, and a cultivated crop. Pages 24 to 27.

3. Grains and corn grown continuously with moderate amounts of manure applied show a decided lowering in yield considering the short time the experiment has been in operation. The average net income per acre has been $5.65, or 35.5 per cent lower than for the better class of rotations. Pages 27 to 32.

4. In the four-year rotation, oats, wheat, clover hay, corn, the corn crop gave an increase in yield of 13.7 per cent, oats 14.95 per cent, and wheat 30.98 per cent, as compared with growing the same crops continuously. Pages 30 to 32.

5. In the four-year rotation, oats, wheat, clover hay, corn, the increases in net income per acre as compared with growing the same crops continuously were as follows: Corn 29.2 per cent, oats 35.2 per cent, and wheat 72.3 per cent. Pages 30 to 32.

6. Commercial fertilizers in the form of raw rock phosphate, acid phosphate, muriate of potash, and sodium nitrate, used singly and in combination, applied to oats and corn in the three-year rotation, oats, clover, corn, did not, for the six-year period, in any instance give consistent increases in yields of any consequence. The soil at the beginning of the experiment was well supplied with organic matter. In each rotation in the fertilizer experiment except the one carried out on Plot 9 of each of the three series, in addition to the commercial fertilizer, six tons of manure were applied each third year preceding the corn. Pages 36 to 45.

7. Indications are that applications of manure are more profitable when made directly to the corn crop than when made to the meadow, preceding the corn. Pages 45 to 47.

8. Yields of corn on fall- and early-spring-plowed clover sod were practically equal. Fall plowing of old meadows or pastures for corn is recommended, as it prevents largely the loss from cutworms. Pages 49 and 50.

9. Oats grown on double-disked spring-plowed corn land were not so satisfactory as on double-disked fall-plowed corn land or on corn land double disked only. When corn land is weedy, low in productivity, or drouthy, plowing in preparation of the seedbed for grain is preferable to double disking only. Pages 50 and 51.

10. The stands of clover and timothy sown with oats on double-disked spring-plowed corn land were more uneven than on double-disked fall-plowed corn land or on corn land double disked only. Pages 50 and 51.

CONCLUSIONS

Results of the experiments for the six-year period warrant the following conclusions:

1. Adopting a systematic rotation of crops in which is included clover and timothy for hay or pasture will ordinarily result in as large a total yield of grains and corn each year as formerly, when the acres were cropped largely to grain and corn only.

2. The net income per acre from the grains and corn grown in rotation with clover or similar legumes may be expected to be higher than from the same crops grown continuously or in rotations not including clover.

CROP ROTATION INVESTIGATIONS

FIELD T EXPERIMENTS

By A. C. Arny

ROTATION OF CROPS

Rotation is a regular succession for a definite period of years of the crops grown on any particular field. The number of fields on which any rotation is carried out usually corresponds to the number of crops in the rotation scheme. The principal objects of rotation are more economical and more certain production of crops throughout a period of years.

GROUPS OF CROPS

There are known fundamental differences in the plants which are grown as field crops, and the methods of preparing the seedbed and the subsequent care vary. Crops may be grouped according to these differences.

GRAINS AND ANNUAL GRASS CROPS

Wheat, oats, barley, flax, and other grains are annual crops with comparatively few roots and occupying largely the upper strata of soil. Little residue is left in the soil by these crops to aid in maintaining the supply of organic matter. The working of the soil each year facilitates decay and the supply of organic matter in the soil is gradually depleted. As these are not dense-growing crops and no intertillage is practiced, weeds grow in them and ripen their seeds. Therefore when grain is grown continuously, weeds become increasingly troublesome.

PERENNIAL GRASS CROPS

Timothy, Kentucky bluegrass, redtop and many other grasses are perennial plants. In growing these crops the soil is not stirred each year, and, as a result, the decay of the organic matter in the soil proceeds slowly. Altho the roots of these plants are not large, their number is so great that they aid in maintaining the supply of vegetable matter in the soil.

LEGUMINOUS CROPS

The clovers, alfalfa, and many other legumes develop heavy and deep root systems which in most instances penetrate deeply into the soil and subsoil. When plowed under, the roots of these crops add very materially to the supply of organic matter in the soil, making it mellow and facilitating drainage. This supply of vegetable matter provides abundant material for the lower forms of plant life that live in the soil to work upon, and as a result plant food is made available in greater abundance.

Leguminous plants do not derive their supply of nitrogen entirely from the soil as do the crops of the other groups. Through association with the bacteria that live in the nodules on their roots, leguminous plants are enabled to appropriate for their use the free nitrogen of the air. Approximately two thirds of the nitrogen contained in a leguminous crop is taken from the air and one third from the soil.[1] Altho a greater amount of nitrogen per acre is removed by leguminous crops than by others, enough remains in the stubble and roots to replace what the crop takes from the soil. When leguminous crops are plowed under, the supply of nitrogen in the soil is increased appreciably. Leguminous crops, as a group, are distinctly "soil builders."

CULTIVATED CROPS

Corn, potatoes, and root crops add very little to the soil in the form of residues. They require thoro preparation of the seedbed each year and frequent intertillage to clean the land of weeds and hasten the decay of the organic matter in the soil and the liberation of plant food. The physical condition of the soil is improved if the growing of crops of this group is not continued so long that the supply of organic matter is greatly lowered.

VALUE OF DIFFERENT ROTATIONS

Since crops vary in themselves and in their effect on the physical condition of soils and the supply of available plant foods in them, it follows that there may be a wide difference in rotations in producing the desired results. Wheat and oats belong to the same group of crops, one does not definitely prepare the soil for the other. Therefore lower yields may be expected from a rotation of these two crops than when either is grown in rotation with clover and corn. In the rotation oats, clover, corn, the clover definitely prepares the soil for corn by increasing the supply of organic matter in it and maintaining or increasing the supply of nitrogen. The cultivation of the corn crop cleans the land of weeds and leaves the soil in good physical condition for the grain crop the following year. This definite inter-relationship of crops which brings about more favorable physical, chemical, and biological conditions in the soil is a feature of all good rotations.

PREVIOUS WORK

In 1894, W. M. Hays and Andrew Boss planned and inaugurated the Field C rotation experiment on forty-four plots at University Farm, "to allow the plants grown in the ordinary field way to tell their own story concerning which scheme of cropping pays best in Minnesota and incidentally to serve in throwing light on our soil problems." Harry Snyder, of the Division of Agricultural Chemistry, coöperated in this investigation, working particularly on the soils of the various plots.

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[1] Hopkins, C. G. Soil fertility and permanent agriculture, page 217. 1910.

The results of the work of the first ten years with the various rotations on these plots were published as Bulletin 109 of the Minnesota Agricultural Experiment Station.[2]

The main points contained in the summaries of the two parts of the bulletin are:

1. "There is choice even among good rotation schemes. In these experiments all those cropping systems gave large net profits in which corn, small grains, and timothy and clover sod laid for one to four years, were arranged in a four- to seven-year rotation, with light manuring once during the course."

2. "The standard five-year rotation . . . first year, corn, following the application of eight tons of manure per acre; second year, wheat; third and fourth years, meadow; fifth year, oats," gave "a net annual income of $5.03 per acre."

Several other rotation schemes were even more profitable than the one used for a standard; while crops grown continuously and crops not properly arranged in the rotation were less profitable or even resulted in a loss.

3. "The experimental evidence (See Part II.) shows that the use of manure and clover add to the nitrogen and that manure, also clover and timothy, add fresh vegetable matter to the soil."

4. "Any systems of cropping that have provided for the maintenance of a supply of vegetable matter in the soil, either by manuring or by growing pasture or meadow crops, have given profitable returns."

In 1898 four rotations were planned for twelve additional continuous plots on Field C. The results of the work for twenty years on the forty-four plots and for ten years on the twelve plots are reserved for another publication.

PURPOSE OF INVESTIGATION

Had there been more land suitable for investigational work available when the Field C rotation experiments were inaugurated, several other promising cropping schemes would have been included. Suitable land became available in 1909 and the Field T rotation investigations were inaugurated. The investigations fall into three groups:

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[2] Hays, W. M.; Boss, Andrew; and Wilson, A. D. The rotation of crops. Minn. Agr. Exp. Sta. Bull. 109, pp. 281-358. 1908.
This bulletin is now out of print.

1. Systems of cropping.
2. Commercial fertilizers in addition to barnyard manure applied in a good rotation.
3. Method of tillage and manuring.

To Andrew Boss and A. D. Wilson belong the credit for planning the investigation and putting it into operation. Since 1909 the writer has been in charge of the work.

HISTORY OF FIELD T

The soil.—The soil is classified by the United States Department of Agriculture as Hempstead silt loam. The surface soil is black silt loam; the subsoil, yellow silt loam underlaid by coarse sand and gravel at a depth of from three to five feet. The surface of the field is level and the under-drainage good throughout.

Previous treatment.—In 1907 wheat, barley, and corn were grown on the field. With the exception of 1907, the cropping had been uniform for the entire field for several years. The applications of barnyard manure were uniform for the entire field. During the ten years previous to 1909, four applications of barnyard manure had been made, at the rate of 10 tons per acre. Therefore, when the experiments were started the soil contained enough organic matter to make it of good texture and it was considered to be relatively uniform in productivity.

FIELD PLAN OF THE FIELD T EXPERIMENTS

The arrangement of the one-tenth-acre plots, the cropping systems, and the legend for each are shown in Figure 1. In each rotation there are as many plots as there are years in the cropping scheme. This provides for the growing of each crop each year.

The first fifteen plots in each of the three series are used in carrying out fifteen different treatments in the same three-year rotation. The plan of cropping followed in each of these fifteen three-year rotations is as follows: The first year oats is sown in the spring and with it 8 pounds of timothy and 6 of medium red clover per acre. The second year two crops of clover are removed or the crop is utilized for pasture. The third year the plots are cropped to corn. Every third year, preceding the corn crop, six tons of stable manure per acre is applied in each rotation except the ones on Plots 4 and 9 in each series, which receive no manure. The details of tillage and fertilization are varied in these rotations in order to learn the effect of different methods of treatment.

STANDARD ROTATIONS

Plots 5 and 12 in each of the three series are used as standards for the first fifteen rotations. The yields in the three-year rotations with the varied treatments are compared with those in these standard rotations.

Fall plowing for corn and double disking of the corn ground in preparing the seedbed for oats is the plan of tillage carried out in these two standard rotations. When the rotations were laid out, there was not enough land in the field to include a three-year standard rotation among Plots 16 to 26 inclusive in each of the three series on which the different cropping schemes are carried out. To remedy this, in the spring of 1915 the seven-year rotation was discontinued and a three-year standard rotation as outlined above was started on three of the released plots. In this publication the yields secured in the five-year rotation carried out on Plots 24 and 25, Series VII and VIII, and Plot 24, Series IX, are used as the standard with which the yields from the different cropping schemes on Plots 16 to 26 inclusive, in each of the three series, are compared.

EFFECT OF CLIMATIC CONDITIONS

Yields are influenced by temperature and rainfall. From 1909 to 1914, inclusive, the temperature during the growing season was approximately normal. Variations in the rainfall, however, influenced the yields.

TABLE I

MONTHLY RAINFALL DURING THE GROWING SEASON, ANNUAL PRECIPITATION, AND DEPARTURE FROM NORMAL, AT ST. PAUL,* 1909-1914

Year	April	May	June	July	Aug.	Sept.	Oct.	Annual	Departure
	In.	In.	In.	In.	In.	In.	In.	In.	In.
1909	2.42	3.37	4.41	3.66	2.89	4.06	2.60	31.82	+ 3.14
1910	0.59	1.76	0.91	0.99	0.98	1.77	0.75	10.21	−18.48
1911	2.22	3.99	5.79	5.15	5.53	5.27	7.55	40.44	+11.76
1912	2.60	4.06	1.10	4.02	4.40	1.27	1.18	21.16	− 7.55
1913	1.62	2.95	3.05	6.11	1.59	3.34	2.03	24.05	− 4.63
1914	3.73	1.48	6.49	0.95	4.48	2.16	1.88	24.62	− 4.06

* The normal annual precipitation at St. Paul is 28.68 inches.

The total precipitation for the six-year period was 19.78 inches below normal.

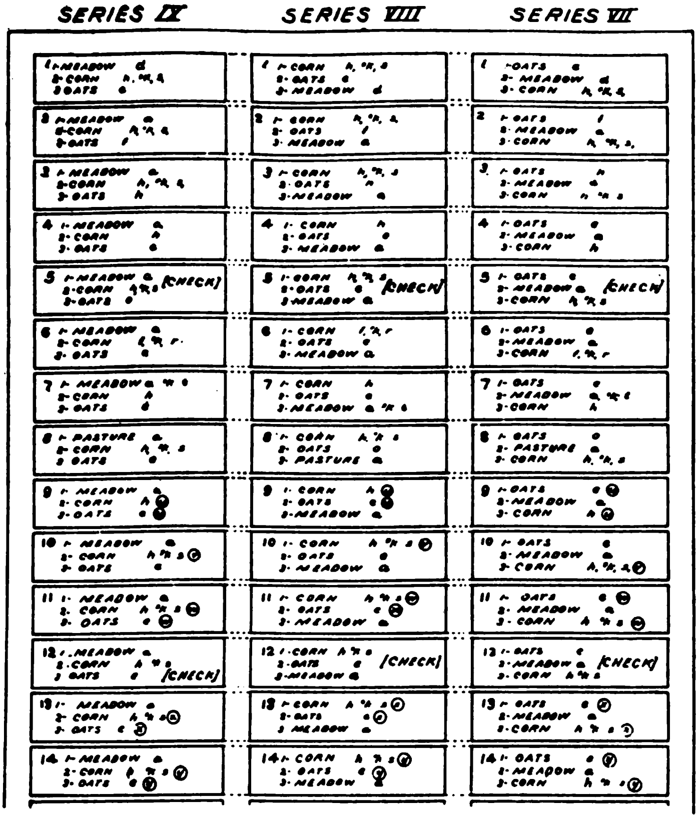
1909. During the growing season the rainfall was 3.14 inches above normal.

1910. The rainfall during the growing season and the total annual precipitation was the lowest on record. Yields were lowered appreciably.

1911. During the growing season the rainfall was abnormally heavy; for the year, 11.76 inches above normal.

1912. The precipitation was heavy during May, very light during June, and heavy during July and August; for the year, 7.55 below normal.

1913. Light rainfall marked the early part of the growing season. During July the rainfall was unusually heavy; during August, very light. For the year, the precipitation was below normal.



SERIES IX	SERIES VIII	SERIES VII
1 1-MEADOW d 2-CORN h, *k, s 3-OATS e	1 1-CORN h, *k, s 2-OATS e 3-MEADOW d	1 1-OATS e 2-MEADOW d 3-CORN h, *k, s
2 1-MEADOW a 2-CORN h, *k, s 3-OATS f	2 1-CORN h, *k, s 2-OATS f 3-MEADOW a	2 1-OATS f 2-MEADOW a 3-CORN h, *k, s
3 1-MEADOW a 2-CORN h, *k, s 3-OATS h	3 1-CORN h, *k, s 2-OATS h 3-MEADOW a	3 1-OATS h 2-MEADOW a 3-CORN h *k s
4 1-MEADOW a 2-CORN h 3-OATS e	4 1-CORN h 2-OATS e 3-MEADOW a	4 1-OATS e 2-MEADOW a 3-CORN h
5 1-MEADOW a [CHECK] 2-CORN h *k s 3-OATS e	5 1-CORN h *k s [CHECK] 2-OATS e 3-MEADOW a	5 1-OATS e 2-MEADOW a [CHECK] 3-CORN h *k s
6 1-MEADOW a 2-CORN l, *k, r 3-OATS e	6 1-CORN l, *k, r 2-OATS e 3-MEADOW a	6 1-OATS e 2-MEADOW a 3-CORN l, *k, r
7 1-MEADOW a *k i 2-CORN h 3-OATS e	7 1-CORN h 2-OATS e 3-MEADOW a *k i	7 1-OATS e 2-MEADOW a, *k i 3-CORN h
8 1-PASTURE a 2-CORN h, *k, s 3-OATS e	8 1-CORN h *k s 2-OATS e 3-PASTURE a	8 1-OATS e 2-PASTURE a 3-CORN h, *k, s
9 1-MEADOW a 2-CORN h [illegible] 3-OATS e [illegible]	9 1-CORN h [illegible] 2-OATS e [illegible] 3-MEADOW a	9 1-OATS e [illegible] 2-MEADOW a 3-CORN h [illegible]
10 1-MEADOW a 2-CORN h *k s [illegible] 3-OATS e	10 1-CORN h *k s [illegible] 2-OATS e 3-MEADOW a	10 1-OATS e 2-MEADOW a 3-CORN h, *k, s [illegible]
11 1-MEADOW a 2-CORN h *k s [illegible] 3-OATS e [illegible]	11 1-CORN h *k s [illegible] 2-OATS e [illegible] 3-MEADOW a	11 1-OATS e [illegible] 2-MEADOW a 3-CORN h *k s [illegible]
12 1-MEADOW a 2-CORN h *k s 3-OATS e [CHECK]	12 1-CORN h *k s [CHECK] 2-OATS e 3-MEADOW a	12 1-OATS e 2-MEADOW a [CHECK] 3-CORN h *k s
13 1-MEADOW a 2-CORN h *k s [illegible] 3-OATS e [illegible]	13 1-CORN h *k s [illegible] 2-OATS e [illegible] 3-MEADOW a	13 1-OATS e [illegible] 2-MEADOW a 3-CORN h *k s [illegible]
14 1-MEADOW a 2-CORN h *k s [illegible] 3-OATS e [illegible]	14 1-CORN h *k s [illegible] 2-OATS e [illegible] 3-MEADOW [illegible]	14 1-OATS e [illegible] 2-MEADOW a 3-CORN h *k s [illegible]

a-Medium red clover 6 lbs. timothy 8 lbs. per acre drilled with grain

b-Mammoth red clover 4 lbs. per acre drilled with grain.

c-Medium red clover 4 lbs., alsike clover 2 lbs., timothy 8 lbs. per acre drilled with grain

d-Medium red clover 6 lbs. timothy 8 lbs per acre sown broadcast

e-Double disced corn or potato land

f-Double disced spring plowed land

h-Double disced fall plowed land

i-Fall plowed; replowed in spring after manure is disced in

*j-Twelve tons manure per acre

*k-Six tons unleached manure per acre

*l-Six tons unleached manure per acre every third year

*m-Six tons unleached manure per acre each year

*n-Eight tons unleached manure per acre

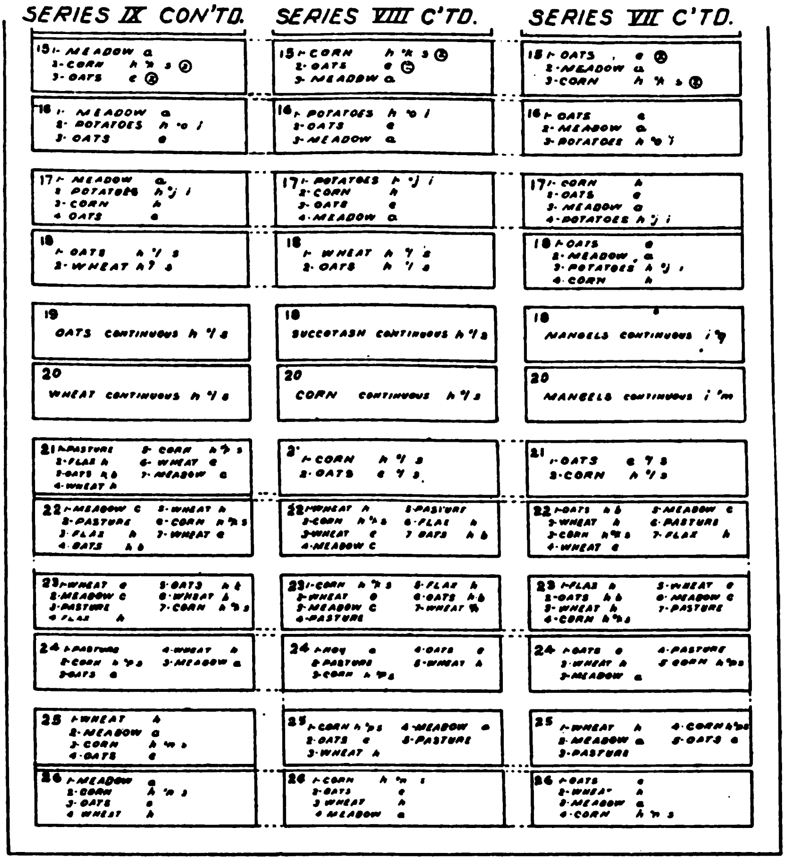
*o-Nine tons unleached manure per acre.

*p-Ten tons unleached manure per acre

*q-Twelve tons unleached manure per acre each year.

Fig. 1. Field Plan of the Investigations.

Methods in Tillage and Manuring, Plots 1 to 8, Inclusive.
Use of Commercial Fertilizer, Plots 9 to 15, Inclusive.



r-manure plowed under.
s-manure disced in.
t-manure applied as top dressing to meadow during winter or early spring.
ⓤ-Acid phosphate 250 lbs., sodium nitrate 300 lbs., muriate of potash 100 lbs. per acre; one half applied to oats and one half to corn
ⓥ-Raw phosphate rock 1000 lbs per acre to corn
ⓦ-Acid phosphate 400 lbs per acre, one half applied to oats and one half to corn
ⓧ-Muriate of potash 200 lbs. per acre; one half applied to oats and one half to corn.
ⓨ-Nitrate of soda 320 lbs per acre, one half applied to oats and one half to corn
ⓩ-Acid phosphate 400 lbs., muriate of potash 200 lbs., nitrate of soda 320 lbs. per acre, one half applied to oats and one half to corn

Fig. 1. Field Plan of the Investigations—*Continued.*
Systems of Cropping, Plots 16 to 26, Inclusive.

1914. The rainfall was light during May, extremely heavy during June, and very light during July. The total annual precipitation was 4.06 inches below normal.

CASH VALUE AND NET INCOME PER ACRE

In the tables and in the discussions, comparisons are made of the yields of a crop grown in the different rotations and in the same rotation with a variation in tillage and manuring. Comparisons are also made on the basis of cash value and net income per acre. For use in the preparation of this publication and to facilitate further comparisons by those interested in the subject, the farm price of field crops on December first of each year is given, with the average for the six-year period, 1909 to 1914 inclusive. These figures were compiled from the Yearbooks of the United States Department of Agriculture. The average yield for the state and the value per acre of the different crops for the period were compiled from the same source. The data in Table II regarding the cost per acre of producing the various farm crops are taken from Bulletin 145, "Cost of Producing Minnesota Farm Products."[3]

TABLE II

FARM PRICE OF FIELD CROPS IN MINNESOTA, DECEMBER 1, 1909-1914, AND AVERAGE FOR SIX YEARS

Year	Wheat	Oats	Corn	Hay	Potatoes
1909	$0.96	$0.35	$0.49	$6.00	$0.35
1910	0.94	0.32	0.45	9.10	0.64
1911	0.92	0.40	0.53	11.90	0.58
1912	0.73	0.26	0.37	6.40	0.28
1913	0.76	0.32	0.53	6.60	0.52
1914	1.02	0.40	0.52	6.10	0.32
Average	$0.888	$0.341	$0.481	$7.68	$0.45

No report is made in the Yearbooks for the mangel crop. The arbitrary price of $1.75 per ton for mangels is used in this publication. Twenty cents per head per month for pasture for sheep has been decided upon, arbitrarily. The three-year average farm price of flax December 1, is $1.45 per bushel.

TABLE III

AVERAGE YIELDS, PRICES, AND VALUES PER ACRE OF MINNESOTA FARM CROPS 1909-1914

	Wheat	Oats	Corn	Hay	Potatoes	Flax
Yield per acre	14.2 bu.	32.0 bu.	35.1 bu.	1.45 tons	108.3 bu.	9.0 bu.
Value per acre	$12.61	$10.91	$16.88	$11.10	$48.52	$13.92

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[3] Peck, F. W. The cost of producing Minnesota farm products, 1908-1912; field crops. Minn. Agr. Exp. Sta. Bull. 145, pp. 1-48. 1914.

TABLE IV

COST PER ACRE (INCLUDING RENTAL) OF PRODUCING MINNESOTA FARM PRODUCTS, 1908-1912

Crop	Method of handling crop	Locality		
		Northfield (Rice County)	Marshall (Lyon County)	Halstad (Norman County)
Wheat	Fall-plowed, stack-threshed	$13.04	$12.61	$10.78
Oats	Fall-plowed, stack-threshed	13.07	12.19	9.96
Flax	Shock-threshed	13.15	....	10.30
Corn	Cut, shocked, and hauled from field	16.86	13.50	13.85
Potatoes	Machine production	....	....	32.18
Hay, clover and timothy, 2 crops	Largely machine production	10.76	10.11	7.74

The cost of production per acre in three representative localities is given. The figures for wheat, oats, corn, and hay used in this publication are from Marshall, Lyon County, as they more nearly represent the average than the other two. Where grain is sown on corn land which has not been plowed, but double disked only, $1.50 per acre is deducted from the costs given in the table. The cost of producing mangels is given as $32.68 in Minnesota Bulletin 117,[4] page 45. The cost of pasture was arrived at in the following manner: Land rent, $3.50 per acre; half the cost of 6 pounds of clover seed at 15 cents and 8 pounds of timothy seed at 10 cents, 85 cents; fence cost per acre per year $1.39.[5] Total cost of pasture per acre $5.74.

SYSTEMS OF CROPPING

Each farm presents a separate problem with regard to the crops that can be produced and utilized to best advantage and the amount of each desired. A rotation which meets the needs on one farm will require some revision on another where conditions are more or less different. These changes can usually be made without in any way altering the essential features.

Several rotations which either had given promise in the preliminary trials on Field C or from the crops included and the sequence would in all probability prove successful, were included in the Field T experiment so as to give a choice among the best.

The growing of potatoes as a regular field crop is becoming a common practice in some parts of the state. Two rotations having potatoes as one of the main crops are included in the experiment.

ORGANIC MATTER NECESSARY

The results of the investigations with rotations on Field C have shown conclusively that those systems of cropping have proved most practical in which provision has been made to maintain the supply of organic matter in the soil, either by growing leguminous crops or by applying manure, or both. In systems of cropping where for purposes of contrast this provision was not made, the yields have been unsatisfactory. Therefore, in the systems of cropping carried out on Field T, Plots 16 to 26, inclusive, in each of the three series, provision was made to at least partially maintain the supply of organic matter in the soil by applying manure. The manure applied was more or less mixed as it was hauled from the barns to large flat-topped piles in the compost yard. It remained in these piles from six months to a year before being hauled to the fields.

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[4] Parker, E. C., and Cooper, T. P. The cost of producing Minnesota farm products, 1902-1907. Minn. Agr. Exp. Sta. Bull. 117, pp. 1-64. 1910.

[5] Gaumnitz, D. A., Wilson, A. D., and Bassett, L. B. Pork production. Minn. Agr. Exp. Sta. Bull. 104, pp. 63-109. 1907.

These bulletins are now out of print.

MANURE APPLIED

Manure is applied in all of the rotations and systems of cropping except the two three-year rotations carried out on Plots 4 and 9 in all three series. It was decided in laying out the rotations that manure should be applied, with certain exceptions, at the rate of two tons per acre per year. In the five-year rotation, ten tons of manure per acre were applied preceding corn in each crop cycle; in the four-year rotation, eight tons of manure were applied; and in the three-year rotation, six tons. In the continuous-cropping schemes six tons of manure were applied each third year, beginning with 1910.

The exceptions to this uniform rate are (1) Mangels grown continuously receive, on Plot 19, twelve tons per acre each year, and on Plot 20, six tons. (2) The three-year potato rotation receives nine tons of manure per acre preceding the potato crop; and the four-year potato rotation, twelve tons. (3) The seven-year rotation receives six tons of manure per acre preceding corn, in each cycle, and clover is sown in the spring with the wheat, preceding the corn, and plowed under in the fall.

ROTATIONS COMPOSED OF ALL OF THE MAIN CLASSES OF CROPS

THE FIVE-YEAR STANDARD ROTATION

See Summary Table XVII, pages 34 and 35

The comparatively satisfactory results secured from the use of the five-year rotation, wheat, hay, hay, oats, corn, on each check plot on Field C made it desirable to include it for further trial in the new investigation where it could be carried out on five plots and each crop be grown every year.

In carrying out a rotation including hay or pasture, it is very necessary to obtain a catch of clover alone or of clover and timothy each year. The five-year rotation was planned so as to give the best possible conditions for obtaining a stand of timothy and clover. On Field C, the oats follow the hay, which in turn is succeeded by corn and wheat. The wheat, and with it the clover and timothy seed, is sown on double-disked and harrowed corn land. Good stands of timothy and clover resulted. There was abundant evidence, however, that changes in the sequence of cropping were necessary from other standpoints. Oats is not well suited to follow meadow and pasture, as it often lodges badly when occupying that place in the rotation. Corn, on the other hand, thrives on land which has been in meadow and pasture.

In the five-year rotation, as included in the Field T experiment, corn follows pasture and oats is grown the next year on the double-disked and harrowed corn land. Following oats in the rotation, the land is fall plowed. Wheat is sown the next spring and with it timothy and clover seed.

Examination of the data on yields, cash value, and net income show clearly that the five-year rotation is one of the most satisfactory in the experiment, yielding crops that average $19.59 in cash value and $8.76 net income per acre for the six-year period. The cash value of each crop exceeds that for the state for the same period by a considerable margin. See Table III. Less lodging of the oat crop takes place in the five-year rotation as carried out on Field T where corn follows the pasture crop, than on Field C where oats follows the pasture. With the exception of 1910, when the rainfall was exceptionally light during the growing season, there has been no difficulty in getting a stand of clover and timothy when sown with the wheat on fall-plowed land.

TABLE V

FIVE-YEAR ROTATION—WHEAT, HAY, PASTURE*, CORN, OATS CHECK

Yields and Cash Values by Plots

	Plot 24—Series VII			Plot 25—Series VII			Plot 24—Series VIII		
Year	Crop	Yield	Cash value	Crop	Yield	Cash value	Crop	Yield	Cash value
1909...	Oats, bu......	72.81	$25.48	Wheat, bu....	28.16	$27.03	Hay, tons....	3.40	$20.40
1910....	Wheat, bu....	23.50	22.09	Hay, tons.....	1.40	12.74	Pasture, mo.. .	No rec	ord
1911...	Wheat, bu....	18.00	16.56	Pasture, mo....	No rec	ord	Corn, bu......	52.08	27.60
1912...	Pasture, mo...	41.30	8.26	Corn, bu......	54.26	20.08	Oats, bu......	65.31	16.98
1913...	Corn, bu......	57.83	30.65	Oats, bu......	77.19	23.70	Wheat, bu....	24.92	18.94
1914...	Oats, bu......	40.00	16.00	Wheat, bu....	23.00	23.46	Hay, tons.....	3.61	22.02
Average...........		......	$19.86	....	......	$21.40	....	......	$21.19

Yields and Cash Values by Plots—*Continued*

	Plot 25—Series VIII			Plot 24—Series IX		
Year	Crop	Yield	Cash value	Crop	Yield	Cash value
1909..........................	Corn, bu......	71.52	$35.04	Pasture, mo...	No rec	ord
1910..........................	Oats, bu......	52.81	16.90	Corn, bu......	38.26	17.22
1911..........................	Wheat, bu....	18.80	17.30	Oats, bu......	47.18	18.87
1912..........................	Hay, tons.....	1.04	6.66	Wheat, bu....	20.33	14.84
1913..........................	Pasture, mo..	44.30	8.86	Hay, tons.....	3.26	21.52
1914..........................	Corn, bu......	61.94	32.21	Pasture, mo..	37.70	7.54
Average..........................	....	......	$19.50	....	......	$16.00

TABLE V—*Continued*

Yields and Cash Values by Crops

Year	Oats		Wheat		Hay		Pasture		Corn	
	Yield	Cash value	Yield	Cash value	Yield	Cash value	Yield	Cash value	Yield	Cash value
	Bu.		Bu.		Tons		Mos.		Bu.	
1909...........	72.81	$25.48	28.16	$27.03	3.40	$20.40	No rec	ord	71.52	$35.04
1910...........	52.81	16.90	23.50	22.09	1.40	12.74	No rec	ord	38.26	17.22
1911...........	47.18†	18.87	18.80	17.30	wheat, bu.‡ 18.00	16.56	No rec	ord	52.08	27.60
1912...........	65.31	16.98	20.33	14.84	1.04	6.66	41.3	$8.26	54.26	20.08
1913...........	77.19	23.70	24.92	18.94	3.26	21.52	44.3	8.86	57.83	30.65
1914...........	40.00§	16.00	23.00	23.46	3.61	22.02	37.7	7.54	61.94	32.21
Average......	59.22	$19.66	23.12	$20.61	2.54‖	$16.67	41.1	$8.22	55.98	$27.13

Average cash value per acre of all crops in the rotation..............................	$19.59
Average cost of production per acre of all crops in the rotation, including pasture at $5.75 per acre..	10.83
Average annual net gain per acre..	$8.76

* Yield of pasture is given on basis of months of pasture furnished for one sheep.

† Oats lodged 80 per cent.

‡ No stand of grass secured in 1910. Wheat and grass seed sown in 1911.

§ Oats lodged 90 per cent.

‖ Five-year average.

THE FOUR-YEAR ROTATION

See Summary Table XVII, pages 34 and 35

Omitting the pasture crop from the five-year rotation, it becomes identical with the four-year rotation, wheat, hay, corn, oats. In average yields of oats and wheat this rotation leads the five-year standard rotation slightly. The hay yields are practically equal. The corn yields, except in 1911, are consistently lower than those of the five-year standard rotation. The greater yields of corn, five years out of six, in the five-year standard rotation, indicate that the state of fertility of the soil is higher in the standard five-year rotation than in the four-year rotation. This is accounted for by the fact that there is one year of pasture in the five-year rotation and no crop is removed from the soil that year.

Lodging of the grain crops is somewhat less prevalent in the four-year rotation than in the five-year. This accounts in part for the slight superiority in the yield of grain in the four-year rotation, as there is always more or less loss in harvesting lodged grain.

In the average cash value of all crops and in net income per acre, the four-year rotation exceeds the five-year standard rotation by a slight margin.

The four-year rotation can be used to advantage on many farms where no pasture is desired, and on others where the pastures are rough land that is not tillable.

TABLE VI
Four-Year Rotation—Oats, Wheat, Hay, Corn*
Yields and Cash Values by Plots

Year	Plot 26—Series VII			Plot 26—Series VIII		
	Crop	Yield	Cash value	Crop	Yield	Cash value
1909	Oats, bu	64.06	$22.42	Corn, bu	64.15	$31.43
1910	Wheat, bu	26.66	25.06	Oats, bu	53.75	17.20
1911	Hay, tons	2.75	32.73	Wheat, bu	17.50	16.10
1912	Corn, bu	48.52	17.95	Hay, tons	1.45	9.28
1913	Oats, bu	65.00	20.80	Corn, bu	54.73	29.01
1914	Wheat, bu	23.67	24.14	Oats, bu	56.25	22.50
Average			$23.85			$20.92

Yields and Cash Values by Plots—*Continued*

Year	Plot 25—Series IX			Plot 26—Series IX		
	Crop	Yield	Cash value	Crop	Yield	Cash value
1909	Wheat, bu	27.16	$26.07	Hay, tons	3.10	$18.60
1910	Hay, tons	0.45	4.10	Corn, bu	35.80	16.11
1911	Corn, bu	61.11	32.39	Oats, bu	46.25	18.50
1912	Oats, bu	74.69	19.42	Oats, bu.†	86.75	22.55
1913	Wheat, bu	30.58	23.24	Hay, tons	2.25	14.85
1914	Hay, tons	4.30	26.23	Corn, bu	57.78	30.05
Average			$21.91			$20.11

Yields and Cash Values by Crops

Year	Oats		Wheat		Hay		Corn	
	Yield	Cash value	Yield	Cash value	Yield	Cash value	Yield	Cash value
	Bu.		Bu.		Tons		Bu.	
1909	64.06	$22.42	27.16	$26.07	3.10	$18.60	64.15	$31.43
1910	53.75	17.20	26.66	25.06	0.45	4.10	35.80	16.11
1911	46.25§	18.50	17.50	16.10	2.75	32.73	61.11	32.39
1912	74.69	19.42	Oats † 86.75	22.55	1.45	9.28	48.52	17.95
1913	65.00	20.80	30.58	23.24	2.25	14.85	54.73	29.01
1914	56.25	22.50	23.67	24.14	4.30	26.23	57.78	30.05
Average	60.00	$20.14	25.11‡	$22.86	2.38	$17.63	53.68	$26.15

Average cash value per acre of all crops in the rotation	$21.70
Average cost of production per acre of all crops in the rotation	11.90
Average annual net gain per acre	$9.80

* Eight tons manure to corn.

† Oats instead of wheat, through error in seeding.

‡ Five-year average.

§ Oats lodged 80 per cent.

TABLE VII

SEVEN-YEAR ROTATION—OATS, WHEAT,* CORN,† WHEAT, HAY, PASTURE, FLAX

Yields and Cash Values by Plots

Year	Plot 23—Series VIII			Plot 21—Series IX			Plot 22—Series IX			Plot 23—Series IX		
	Crop	Yield	Cash value	Crop	Yield	Cash value	Crop	Yield	Cash value	Crop	Yield	Cash value
1909	Corn, bu	65.27	$31.98	Pasture, mo	No re	cord	Barley, bu	41.66	$19.58	Wheat, bu	29.16	$27.99
1910	Wheat, bu	21.50	20.21	Flax, bu	No re	cord	Pasture, mo	No re	cord	Hay, tons	1.15	10.47
1911	Whea	16.83	15.48	Oats, bu	39.06	$15.62	Flax, bu	No re	cord	Pasture, mo	No re	cord
1912	Pasture, mo	8.20	11.64	Wheat, bu	21.00	15.33	Oats, bu	39.38	10.24	Flax, bu	No re	cord
1913	Flax, bu	[illegible].29	36.67	Corn, bu	59.91	31.75	Wheat, bu	28.33	21.53	Oats, bu	65.63	21.00
1914	Oats, bu	59.38	23.75	Wheat, bu	21.33	21.76	Corn, bu	57.50	29.90	Wheat, bu	22.67	23.12
Average			$23.29			$21.12			$20.31			$20.65

Yields and Cash Value by Plots—*Continued*

Year	Plot 22—Series VII			Plot 23—Series VII			Plot 22—Series VIII		
	Crop	Yield	Cash value	Crop	Yield	Cash value	Crop	Yield	Cash value
1909	Oats, bu	75.31	$26.36	Flax, bu	10.00	$14.50	Wheat, bu	15.00	$14.40
1910	Wheat, bu	20.50	19.27	Oats, bu	43.75	14.00	Corn, bu	30.18	13.58
1911	Corn, bu	57.63	30.54	Wheat, bu	21.83	20.08	Wheat, bu	19.66	18.09
1912	Wheat, bu	20.33	14.84	Corn, bu	50.11	14.54	Hay, tons	1.35	8.64
1913	Hay, tons	3.03	20.00	Wheat, bu	28.50	21.66	Pasture, mo	41.30	8.26
1914	Pasture, mo	73.30	14.66	Hay, tons	4.65	28.37	Flax, bu	16.96	24.59
Average			$20.95			$19.53			$14.59

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* 4 lbs. Mammoth red clover sown with wheat and plowed under.

† Six tons of manure per acre.

‡ No stand of grass secured in 1910, wheat substituted.

‡ Six tons of manure per acre.

TABLE VII—*Continued*

Yields and Cash Values by Crops

Year	Wheat		Hay		Pasture		Flax		Oats		Wheat		Corn	
	Yield	Cash value	Yield	Cash value	Yield	Cash value	Yield	Cash value	Yield	Cash value	Yield	Cash value	Yield	Cash value
	Bu.		Tons Barley bu.		Mo.		Bu.		Bu.		Bu.		Bu.	
1909	29.16	$27.99	41.66	$19.58	....	....	10.00	$14.50	75.31	$26.36	15.00	$14.40	65.27	$31.98
1910	21.50	20.21	1.15	10.47	....	....	....	....	43.75	14.00	20.50	19.27	30.18	13.58
			Wheat, bu.											
1911	19.66	18.09	16.83	15.48	....	....	....	....	39.06§	15.62	21.83	20.08	57.63	30.54
1912	20.33	14.84	1.35	8.64	58.2	$11.64	....	....	39.38§	10.24	21.00	15.33	50.11	18.54
1913	28.50	21.66	3.03	20.00	41.3	8.26	25.29	36.67	65.63	21.00	28.33	21.53	59.91	31.75
1914	21.33	21.76	4.65	28.37	73.3	14.66	16.96	24.59	59.38	23.75	22.67	23.12	57.50	29.90
Average	23.41	$20.76	2.55‖	$17.09	57.6	$11.52	17.42	$25.25	53.75	$18.50	21.56	$18.96	53.43	$26.05

§ Oats lodged badly.

‖ Four-year average.

Average cash value of all crops in the rotation....................$19.96

Average cost of production per acre of all crops in the rotation $10.90

Average annual net gain per acre .... $ 9.06

THE SEVEN-YEAR ROTATION

See Summary Table XVII, pages 34 and 35

The seven-year rotation, oats, wheat, corn, wheat, hay, pasture, flax, provides for four sevenths of the land in grain each year; one seventh to a cleaning crop (corn in this instance but potatoes or a part in each would answer the purpose just as well); and a hay and a pasture crop which restore organic matter and nitrogen to the soil. Less manure is applied per acre per year than in the five-year standard rotation, but clover seed is sown with the wheat crop preceding corn and the clover plowed under in October the same year. This rotation includes flax, which should not be grown on the same field oftener than once in six or seven years unless both the seed and the soil are known to be free from wilt, a parasitic disease of the flax plant.

In yields, cash values, and average annual net income per acre for six years, this rotation compares very favorably with the five-year standard rotation and exceeds the continuous-cropping schemes by a good margin.

The results indicate that on farms where it is desirable to continue producing grain largely, the use of this rotation or a similar one will give better yields than cropping to grains continuously.

THE FOUR-YEAR POTATO ROTATION

See Summary Table XVII, pages 34 and 35

The four-year potato rotation, oats, hay, potatoes, corn, differs from the common four-year rotation discussed on page 18, in having one less grain crop and one more cultivated crop. With two cultivated crops in the rotation the supply of organic matter is depleted more rapidly than with only one. Therefore manure at the rate of three tons per acre per year, a total of 9 tons, is applied preceding the potatoes. This is one ton per acre per year more than is applied in the five-year standard rotation.

In this rotation oats have lodged regularly except in 1910, when the rainfall during the growing season was extremely light. This has materially reduced the average yield. The yields of corn do not indicate a higher productivity of the soil in this rotation than in the five-year standard rotation.

The yields of potatoes have varied widely, owing to seasonable differences, stands secured, and the ravages of preventable diseases.

The net income per acre exceeds that of the five-year standard rotation by a small margin, and that of the three-year potato rotation by $4.04.

TABLE VIII

FOUR-YEAR POTATO ROTATION—OATS, HAY, POTATOES,* CORN

Yields and Cash Values by Plots

Year	Plot 17—Series VII			Plot 18—Series VII		
	Crop	Yield	Cash value	Crop	Yield	Cash value
1909	Corn, bu.	63.88	$31.30	Oats, bu.	70.31	$24.61
1910	Oats, bu.	36.87	11.80	Hay, tons	1.00	9.10
1911	Hay, tons	2.85	33.91	Potatoes, bu.	41.66	24.16
1912	Potatoes, bu.	93.33	26.13	Corn, bu.	51.01	18.87
1913	Corn, bu.	57.65	30.55	Oats, bu.	79.69	25.50
1914	Oats, bu.	60.31	24.12	Hay, tons	4.51	27.51
Average			$26.30			$21.63

Yields and Cash Values by Plots—*Continued*

Year	Plot 17—Series VIII			Plot 17—Series IX		
	Crop	Yield	Cash value	Crop	Yield	Cash value
1909	Potatoes, bu.	153.33	$53.67	Hay, tons	3.50	$21.00
1910	Corn, bu.	42.47	19.11	Potatoes, bu.	75.83	48.53
1911	Oats, bu.	38.43	15.37	Corn, bu.	50.00	26.50
1912	Hay, tons	1.94	12.42	Oats, bu.	22.50	5.85
1913	Potatoes, bu.	35.00	18.20	Hay, tons	2.58	17.03
1914	Corn, bu.	52.08	27.08	Potatoes, bu.	240.00	76.80
Average			$24.31			$32.62

Yields and Cash Values by Crops

Year	Oats		Hay		Potatoes		Corn	
	Yield	Cash value	Yield	Cash value	Yield	Cash value	Yield	Cash value
	Bu.		Tons		Bu.		Bu.	
1909	70.31	$24.61	3.50	$21.00	153.33	$53.67	63.88	$31.30
1910	36.87	11.80	1.00	9.10	75.83	48.53	42.47	19.11
1911	38.43†	15.37	2.85	33.91	41.66	24.16	50.00	26.50
1912	22.50‡	5.85	1.94	12.42	93.33	26.13	51.01	18.87
1913	79.69	25.50	2.58	17.03	35.00	18.20	57.65	30.55
1914	60.31	24.12	4.51	27.51	240.00	76.80	52.08	27.08
Average	51.35	$17.88	2.73	$20.16	106.53	$41.25	52.85	$25.74

Average cash value per acre of all crops in the rotation	$26.22
Average cost of production per acre of all crops in the rotation	16.80
Average annual net gain per acre	$9.42

* Twelve tons of manure to potatoes.

† Oats lodged 30 per cent.

‡ Oats lodged early, 90 per cent.

THE THREE-YEAR POTATO ROTATION

See Summary Table XVII, pages 34 and 35

In yields of oats and hay the three-year potato rotation leads the five-year standard rotation by a slight margin. The low yields of potatoes and the high cost of production make the net gain per acre from all three crops in the rotation $5.38, as compared with $8.76 for the five-year standard rotation.

The six-year average yields of potatoes in the four-year and the three-year potato rotations are 106.53 and 99.99 bushels, respectively. This is not a wide difference. Lodging of the oat crop has not been so general in the three-year rotation as in the four-year, which explains largely the difference in yields of this crop. The six-year average net income per acre is $9.42 for the four-year potato rotation and $5.38 for the three-year rotation.

TABLE IX

THREE-YEAR ROTATION—OATS, HAY, POTATOES*—POTATO ROTATION

Yields and Cash Values by Plots

Year	Plot 16—Series VII			Plot 16—Series VIII			Plot 16—Series IX		
	Crop	Yield	Cash value	Crop	Yield	Cash value	Crop	Yield	Cash value
1909...	Oats, bu.....	75.00	$26.25	Potatoes, bu..	138.33	$48.43	Hay, tons....	3.65	$21.90
1910...	Hay, tons....	1.00	9.10	Oats, bu.....	53.43	17.10	Potatoes, bu..	73.33	46.93
1911...	Potatoes, bu..	31.66	18.36	Hay, tons....	2.95	35.11	Oats, bu.....	41.25	16.50
1912...	Oats, bu.....	74.96	19.49	Potatoes, bu..	103.33	28.93	Hay, tons....	1.70	10.88
1913...	Hay, tons....	2.84	18.74	Oats, bu.....	80.31	25.70	Potatoes, bu..	50.00	26.00
1914...	Potatoes, bu..	203.33	65.07	Hay, tons....	3.91	23.85	Oats, bu.....	36.25	14.50
Average...........		......	$26.17		......	$29.85		......	$22.79

Yields and Cash Values by Crops

Year	Oats		Hay		Potatoes	
	Yield	Cash value	Yield	Cash value	Yield	Cash value
	Bu.		Tons		Bu.	
1909....................	75.00	$26.25	3.65	$21.90	138.33	$48.43
1910....................	53.43	17.10	1.00	9.10	73.33	46.93
1911....................	41.25	16.50	2.95	35.11	31.66	18.36
1912....................	74.96	19.49	1.70	10.88	103.33	28.93
1913....................	80.31	25.70	2.84	18.74	50.00	26.00
1914....................	36.25	14.50	3.91	23.85	203.33	65.07
Average...............	60.20	$19.92	2.68	$19.93	99.99	$38.95

Average cash value per acre of all crops in the rotation..............................	$23.27
Average cost of production per acre of all crops in the rotation......................	17.89
Average annual net gain per acre..	$5.38

*Nine tons of manure per acre.

ROTATIONS COMPOSED OF TWO CLASSES OF CROPS OR TWO CROPS OF THE SAME CLASS

OATS AND WHEAT GROWN ALTERNATELY

See Summary Table XVII, pages 34 and 35

Comparing the system of growing two crops of the same class alternately with the five-year standard rotation on the basis of the oat crop only, it will be noted that with the exception of the first year and the year 1911, when the oats in the five-year standard rotation lodged 90 per cent, the yields were decidedly lower than in the five-year standard rotation.

The six-year average yield of oats is greater in the five-year standard rotation by 3.93 bushels per acre and the value by 92 cents.

Making the comparison on the basis of the wheat crop, the advantage in yield the first year was again with the wheat and oats grown alternately and also in 1911. In 1912 there was practically no difference in the yields. In three years out of six, the wheat in the five-year standard rotation gave the better yield. The six-year average yield is in its favor by 1.30 bushels and the value per acre by $1.23.

TABLE X

TWO-YEAR ROTATION—OATS, WHEAT*

Year	Yields and Cash Values by Plots						Yields and Cash Values by Crops			
	Plot 18—Series VIII			Plot 18—Series IX			Oats		Wheat	
	Crop	Yield	Cash value	Crop	Yield	Cash value	Yield	Cash value	Yield	Cash value
		Bu.			Bu.		Bu.		Bu.	
1909	Wheat	30.10	$28.90	Oats	76.25	$26.69	76.25	$26.69	30.10	$28.90
1910	Oats	40.31	12.90	Wheat	19.33	18.17	40.31	12.90	19.33	18.17
1911	Wheat	19.33	17.78	Oats	48.75	19.50	48.75	19.50	19.33	17.78
1912	Oats	59.38	15.44	Wheat	20.00	14.60	59.38	15.44	20.00	14.60
1913	Wheat	23.83	18.11	Oats	61.09	19.55	61.09	19.55	23.83	18.11
1914	Oats	45.94	18.38	Wheat	18.33	18.70	45.94	18.38	18.33	18.70
Six-year average		....	$18.59	....	....	$19.54	55.29	$18.74	21.82	$19.38
Six-year average value per acre										$19.06
Average cost of production										12.40
Average annual net gain per acre										$ 6.66

* Six tons of manure every third year, beginning 1910.

Making the comparison on the basis of the net gain per acre on all of the crops in each system, the advantage is in favor of the five-year standard rotation by $2.10. Both the oats and the wheat in this system surpass in both yield and net income per acre the oats and the wheat grown continuously.

TABLE XI

CONTINUOUS CROPPING—OATS AND WHEAT

Year	Yields and Cash Values by Plots and Crops					
	Plot 19—Series IX			Plot 20—Series IX		
	Crop	Yield	Cash value	Crop	Yield	Cash value
		Bu.			Bu.	
1909	Oats	74.06	$25.92	Wheat	28.33	$27.20
1910	Oats	36.56	11.70	Wheat	15.50	14.57
1911	Oats	50.31	20.12	Wheat	13.50	12.42
1912	Oats	56.88	14.79	Wheat	11.67	8.52
1913	Oats	53.44	17.11	Wheat	22.00	16.72
1914	Oats	35.94	14.38	Wheat	13.00	13.26
Six-year average		51.03	$17.34	....	17.33	$15.45
Six-year average value per acre			$17.34			$15.45
Average cost of production			12.19			12.61
Average annual net gain per acre			$5.15			$2.84

OATS AND CORN GROWN ALTERNATELY

See Summary Table XVII, pages 34 and 35

The yields of oats in the oats and corn rotation have varied widely. In 1911 the oats lodged as badly as in the five-year standard rotation and the yield was lowered in consequence. The low yield in 1912 cannot be accounted for, as the crop, before cutting, gave every evidence of producing well. Manure was applied in 1913 and this accounts for the high yield that year, altho the crop lodged 20 per cent. The oats in this rotation yielded for the six-year period 1.5 bushels less than in the five-year standard rotation. This difference is so small that the two systems of cropping may be considered to have been equally efficient during the six-year period in the production of oats.

Comparing this system with the five-year standard rotation on the basis of the yields of corn, a decided and consistently higher yield was obtained in the five-year standard rotation during the last four years of the period. The six-year average yield of corn per acre in the oats-corn rotation is 47.34 bushels as compared with an average of 55.98 bushels for the five-year standard rotation for the same period.

The yields of corn for the six-year period in this system and in that of corn grown continuously are 47.34 and 46.34 bushels per acre, respectively, indicating that the two systems were approximately of equal value.

During the six-year period, the average yield of oats in the two-year rotation made up of oats and corn approximated very closely that in the five-year standard rotation. On the other hand, the corn yields in this system approached very closely the lower level of production obtained from cropping to corn continuously.

TABLE XII

TWO-YEAR ROTATION—OATS, CORN*

Year	Yields and Cash Values by Plots						Yields and Cash Values by Crops			
	Plot 21—Series VII			Plot 21—Series VIII			Oats		Corn	
	Crop	Yield	Cash value	Crop	Yield	Cash value	Yield	Cash value	Yield	Cash value
		Bu.			Bu.		Bu.		Bu.	
1909.....	Oats.....	71.87	$25.14	Corn.....	61.97	$30.37	71.87	$25.14	61.97	$30.37
1910.....	Corn.....	39.50	17.78	Oats.....	43.12	13.80	43.12	13.80	39.50	17.78
1911.....	Oats.....	39.06	15.62	Corn.....	41.66	22.08	39.06	15.62	41.66	22.08
1912.....	Corn.....	45.93	16.99	Oats.....	35.00	9.10	35.00	9.10	45.93	16.99
1913.....	Oats.....	94.06	30.10	Corn.....	45.37	24.05	94.06	30.10	45.37	24.05
1914.....	Corn.....	49.58	25.78	Oats.....	63.13	25.25	63.13	25.25	49.58	25.78
Average	....	....	$21.90	....	....	$20.78	57.71	$19.84	47.34	$22.84

Average value per acre..	$21.34
Average cost of production..	12.50
Average net profit per acre..	$8.84

* Six tons of manure each third year, beginning in 1910.

TABLE XIII

CONTINUOUS CROPPING—OATS AND CORN

Year	Plot 19—Series IX			Plot 20—Series VIII		
	Crop	Yield	Cash value	Crop	Yield	Cash value
		Bu.			Bu.	
1909	Oats	74.06	$25.92	Corn	69.01	$33.81
1910	Oats	36.56	11.70	Corn	35.29	15.88
1911	Oats	50.31	20.12	Corn	47.50	25.18
1912	Oats	56.88	14.79	Corn	35.15	13.01
1913	Oats	53.44	17.11	Corn	45.79	24.27
1914	Oats	35.94	14.38	Corn	43.33	22.53
Average		51.03	$17.34		46.34	$22.45
Average value per acre			$17.34			$22.45
Average cost of production			12.19			13.50
Average net profit per acre			$5.15			$8.95

CONTINUOUS-CROPPING SCHEMES

OATS GROWN CONTINUOUSLY

See Table XI, page 25, and Summary Table XVII, pages 34 and 35

With the exceptions of the first year and the year 1911, when the oat crop in the five-year standard rotation lodged badly, the yields of oats are consistently lower in the continuous-cropping scheme than in the five-year standard rotation. Practically no lodging has taken place in the oats grown continuously. The six-year average advantage in favor of the five-year rotation on the oat crop alone is 8.19 bushels per acre, and a value of $2.32. At the rate of the yields obtained for the six-year period, one acre of oats in the five-year standard rotation returned as large a profit as 1.45 acres grown continuously. The average net income per acre in the five-year standard rotation, including all the crops, was $8.76, as compared with $5.15 for oats grown continuously. Including all of the crops grown in the five-year standard rotation, the advantage in net income per acre in its favor over the oats grown continuously is still greater than when the oat crop alone is made the basis for comparison.

Oats grown continuously have produced lower yields and net incomes per acre than the same crop grown either alternately with wheat or with corn or in rotation with clover and corn.

WHEAT GROWN CONTINUOUSLY

See Table XI, page 25, and Summary Table XVII, pages 34 and 35

In the first year of the experiment the yield of wheat in the five-year standard rotation was 28.16 bushels and in the continuous-wheat plot, 28.33 bushels. In the other five years the yield of wheat grown continuously was decidedly less than of that grown in the five-year standard rotation. The six-year average yield of wheat in the five-year standard rotation is 23.12 bushels per acre; and when grown continuously, 17.33 bushels per acre. This is a difference in yield of 5.79 bushels and in value per acre of $5.16, in favor of the wheat grown in the five-year standard rotation over that grown continuously. Under similar conditions, one acre of wheat grown in the five-year standard rotation would return as great a net income as 2.8 acres grown continuously.

The average net income per acre in the five-year standard rotation, including all the crops, was $8.76 per acre as compared with $2.84 for the wheat grown continuously. When the two systems of cropping are compared on the basis of the average net income per acre from all the groups grown in each, the advantage is still greater in favor of the five-year rotation than when the comparison is made on the basis of the wheat crop only.

Alternating wheat with oats gave for the six-year period yields of this crop approximating very closely the yields of wheat in the five-year standard rotation. With the exception of the mangel crop, the wheat grown continuously yielded the lowest net income per acre of any system of cropping in the experiment.

OATS AND WHEAT MIXED, GROWN CONTINUOUSLY

See Summary Table XVII, pages 34 and 35

Oats and wheat are frequently grown together for the purpose of increasing the yield and reducing the lodging on highly productive soils. No increase in yield resulted from the use of the mixture in this experiment during the first four years. Since 1913, when the proportion of wheat and oats and the amount of seed per acre were changed, the yields have been in favor of the mixture.

By actual count it was found that wheat and oats mixed averaged 131 plants and 177 culms per square yard, and wheat grown continuously, practically the same number. Oats grown continuously averaged 142 plants and 210 culms per square yard. The number of plants and culms per acre did not vary widely in 1913 and 1914. From these counts it is evident that there was no advantage in favor of the mixed crop so far as number of plants or culms is concerned.

The soil is not maintained in a sufficiently high state of productivity by this system of cropping to cause lodging. The results up to the present time do not warrant any conclusions being drawn.

CORN GROWN CONTINUOUSLY

See Summary Table XVII, pages 34 and 35

In the first year of the experiment, the plot of corn grown continuously yielded within a bushel and a half per acre of that in the five-year standard rotation. In each of the other five years the yield of corn grown continuously was lower than that in the five-year standard rotation, the six-year averages being 46.34 bushels and 55.98 bushels, respectively, or 9.6 bushels per acre in favor of the corn in rotation. Comparing the two systems of cropping on the basis of net income per acre on the corn crop only, there is an advantage in favor of corn in rotation of $4.68 per acre.

Making the comparison of the two systems of cropping on the basis of the average net income per acre from all the crops included in each system, the six-year results are practically equal. The results with corn grown continuously with applications of manure show that yields have not been maintained during the short preliminary period, while the five-year standard rotation appears adequate in this respect. Even on the exceptional farm where enough manure is available to maintain the soil in a high state of productivity, corn should be grown in a rotation in order to obtain the benefit of cleaning the land of weeds and getting rid of harmful insect pests.

TABLE XIV

CONTINUOUS CROPPING—WHEAT,* OATS,* AND WHEAT AND OATS MIXED*

Year	Yields and Cash Values per Acre								
	Plot 19—Series IX			Plot 20—Series IX			Plot 19—Series VIII		
	Crop	Yield	Cash value	Crop	Yield	Cash value	Crop	Yield	Cash value
		Lbs.			Lbs.			Lbs.	
1909...	Oats........	2,370	$25.92	Wheat.......	1,700	$27.20	Wheat &Oats	2,590†	......
1910...	Oats........	1,170	11.70	Wheat.......	930	14.57	Wheat &Oats	900	......
1911...	Oats........	1,610	20.12	Wheat.......	810	12.42	Wheat &Oats	1,150	......
1912...	Oats........	1,820	14.79	Wheat.......	700	8.52	Wheat &Oats	1,690	......
1913...	Oats........	1,700	17.11	Wheat.......	1,320	16.72	Wheat &Oats	1,840	$19.60
1914...	Oats........	1,150	14.38	Wheat.......	780	13.26	Wheat &Oats	1,180	16.16
Average...........		1,636.7	$17.34	....	1,040	$15.45	....	1,668	$17.86

* Six tons of manure per acre each third year, beginning in 1910.

† Fifty-six pounds per acre of a mixture of 32 pounds of oats and 38 of wheat. In 1913 the rate was changed to 96 pounds per acre, consisting of 32 pounds of oats and 64 of wheat.

MANGELS GROWN CONTINUOUSLY

See Summary Table XVII, pages 34 and 35

Approximately 18 tons of mangels must be grown per acre to pay the cost of production. Somewhat lower yields than this may be profitable if mangels are fed to livestock in small amounts. In order that the yield of mangels may be large enough for a reasonable profit, the productivity of the soil must be above the average. On land that will produce profitable yields of mangels, grain crops usually lodge badly, therefore it is not ordinarily practical to raise mangels in the usual farm rotations. The experiment of growing magels continuously with applications of manure each year was outlined to ascertain if this method can be carried on profitably for a period of years. Referring to Table XV it is seen that the plot receiving 6 tons of manure per acre produced, as a five-year average, 14.68 tons per acre, while the plot receiving 12 tons of manure produced 17.72 tons. At $1.75 per ton, in neither instance is the yield sufficient to pay the actual cost of production. The plot receiving 12 tons of manure per acre each year produced 2.84 tons of mangels worth $4.97 more than the one receiving 6 tons of manure per acre. The additional six tons of manure applied produced mangels worth $4.97 per acre. This is a return of 82 cents per ton for the manure.

TABLE XV
CONTINUOUS CROPPING—MANGELS*

Year	12 tons manure per acre			6 tons manure per acre		
	Plot 19—Series VII			Plot 20—Series VII		
	Crop	Yield	Cash value	Crop	Yield	Cash value
		Tons			Tons	
1909	Mangels	20.60	$36.05	Mangels	31.60	$55.30
1910	Mangels	13.25	23.19	Mangels	15.01	26.27
1911	Mangels	25.50	44.63	Mangels	22.15	38.76
1912	Mangels	20.90	36.58	Mangels	18.45	32.29
1913	Mangels	20.01	35.02	Mangels	13.75	24.06
1914	Mangels	8.95	5.66	Mangels	5.05	8.84
Five-year average		17.72	$31.01		14.88	$26.04

* Differences in stand in 1909 make the yields for that year not comparable.

Diseases of the root crop which usually reduce the yields of mangels grown continuously on the same ground, have not, during the first 6 years, entered to any extent as a factor in the experiment.

A GOOD ROTATION VERSUS CONTINUOUS CROPPING

Following a good systematic crop rotation on any farm instead of cropping continuously, means that from one seventh to two fifths of the land, according to the plan followed, ordinarily should be given over to the production of hay or pasture. This reduces proportionately the acreage of grain and corn. That this practice need not reduce the total number of bushels of grain and corn produced or the average net profit per acre on the farm as a whole, is plainly evident upon comparing the regular four-year rotation, Table VI, and the continuous-cropping schemes, Tables XI, XIII, and XV.

TABLE XVI
FOUR-YEAR ROTATION AND CONTINUOUS CROPPING, SIX-YEAR AVERAGE PER ACRE

System	Corn		Oats		Wheat		Clover	
	Yield	Net income	Yield	Net income	Yield	Net income	Yield	Net income
	Bu.		Bu.		Bu.		Tons	
Four-year rotation	53.68	$12.65	60.00	$7.95	25.11	$10.25	2.38	$7.52
Continuous cropping	46.34	8.95	51.03	5.15	17.33	2.84	*	*
Increase due to rotation	7.34	$3.70	8.97	$2.80	7.78	$7.41		

* Clover was not grown continuously.

Judging from the results obtained in the rotation experiments on Field C, more striking results may be expected when the experiment has been continued for from 10 to 20 years. However, during the short period of six years, increase in yield due to rotation is 13.7 per cent for corn, 14.95 per cent for oats, and 30.98 per cent for wheat. At this rate, 6 acres of corn in the four-year rotation would produce as many bushels as 7 acres under the continuous-cropping system. Likewise, 6 acres of oats under the rotation would yield as many bushels as 7 acres cropped continuously; and 2 acres of wheat in the rotation would yield as much as 3 acres cropped continuously.

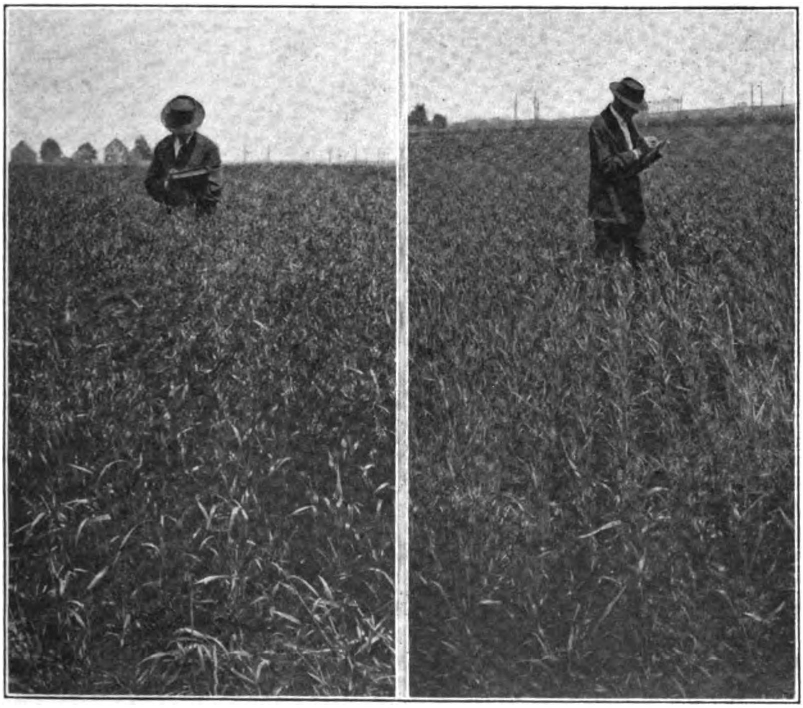

Fig. 2. Comparison of Oats in Four-Year Rotation (at left) and Oats Grown Continuously (at right)

For the first six years of cropping under these two systems, the oats in the rotation gave 14.95 per cent greater yield and 35.2 per cent greater income. The photographs, taken July 6, show wherein the difference lies.

On land of medium productivity, by following a good rotation, one acre in seven of the corn and oats and one in three of the wheat would be released for clover, without any reduction in the total yield.

The increase in net income per acre due to the larger yields obtained without a proportionate increase in the cost of production, was: for corn, 29.2 per cent; oats, 35.2 per cent; and wheat, 72.3 per cent.

Therefore, reducing, by following a good rotation system, the acreage of corn or oats one seventh, or of wheat one third, would not necessarily reduce the total yield; and the net income per acre for the smaller acreage in these crops would be increased.

Under these circumstances, if no use were made of the clover from the land released to this crop, the total net income would still be greater than if the whole farm were cropped to grain or corn continuously.

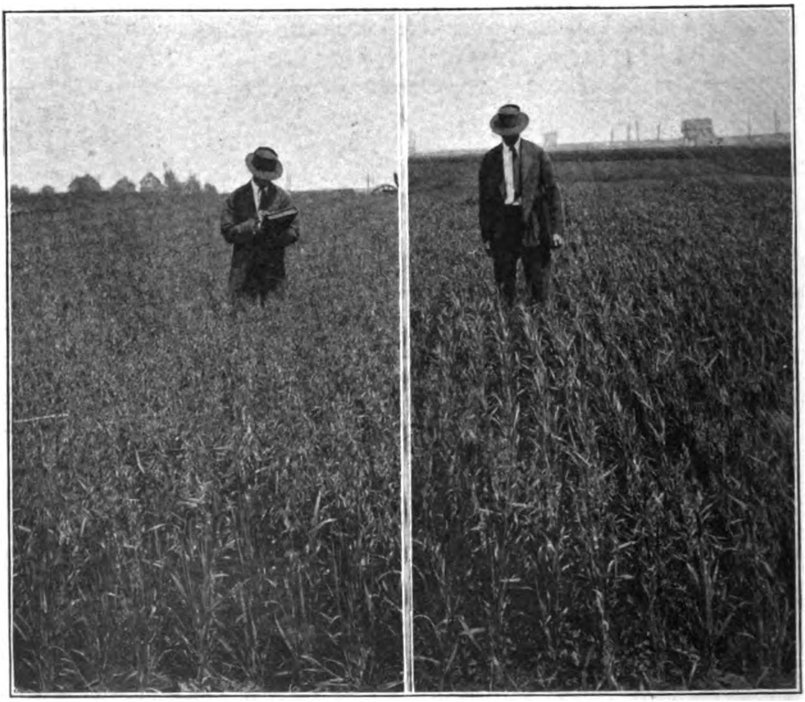

Fig. 3. Comparison of Oats Alternated With Corn (at left) and Oats Alternated With Wheat (at right)

For the first six years of cropping under the two systems, the oats alternated with corn approximated very closely the yields obtained in the four-year rotation, while the oats alternated with wheat failed to reach that yield by four bushels per acre.

Crops in rotation remove more plant food from the soil than continuous cropping. Each pound of grain, straw, and hay harvested removes from the soil, within narrow limits, certain amounts of phosphorus and potash. The amount of nitrogen removed per pound of crop varies more than that of phosphorus and potash, more being removed from soils containing large amounts. The larger the crop removed, the greater the draft on the soil of the substances mentioned. In every instance, the yields in the four-year rotation have been decidedly greater than in the continuous-cropping schemes; consequently more phosphorus, potash, and nitrogen have been removed from the soil. The supply of organic matter and nitrogen is maintained in the four-year rotation by growing leguminous crops and applying moderate amounts of manure. More phosphorus and potash are removed in the crops in the four-year rotation than are returned in the manure applied. Therefore a supply of these two substances from outside sources will be necessary sooner in the four-year rotation than in the continuous-cropping scheme.

RESULTS OF THE SYSTEMS-OF-CROPPING INVESTIGATIONS

1. The rotations made up of grains, clovers, and cultivated crops with moderate applications of manure are maintaining yields and have, with one exception, returned net incomes of $8.76 or more per acre for the six-year period.

2. The rotations made up of different grains alternated or grain and corn alternated, having manure applied at the same rate as in the better class of rotations, have not maintained yields. The net income per acre, $6.66 for the oats-wheat rotation, is not so high as was obtained in the rotations made up of grains, clovers, and cultivated crops, with manure applied preceding corn. The rotation made up of oats and corn returned a net income of $8.84 per acre for the six-year period.

3. The yields obtained in the continuous-cropping schemes with manure applied at the rate of 2 tons per acre per year, a total application of 6 tons per acre each third year, are strikingly low considering the short period of time that the experiment has been in operation. The yields are consistently lower than those obtained in the better rotations which are made up of grain, grasses, legumes, and cultivated crops, and somewhat inferior to those obtained in the second-rate rotations, which are made up of grains only or grains and cultivated crops only. The net income per acre has been $2.84 for wheat, $5.15 for oats, and $8.95 for corn, or an average of $5.65 for the three.

4. When grown in a four-year rotation with clover and timothy hay, corn gave an increase in yield of 13.7 per cent, oats 14.95 per cent and wheat 30.98 per cent, as compared with growing the same crops continuously.

5. In the four-year rotation system, without a proportionate increase in the cost of production, the net income per acre increased as follows: Corn 29.2 per cent, oats 35.2 per cent, and wheat 72.3 per cent, as compared with the net income per acre obtained from growing the same crops continuously.

6. Growing mangels continuously with 6 and 12 tons of manure per acre applied annually, respectively, did not in either case yield a product equal to the cost of production.

TABLE XVII
SUMMARY OF YIELDS AND CASH VALUES—SYSTEMS-OF-CROPPING EXPERIMENT

System of cropping	Length in years	Yield and cash values by crops									
		Oats		Hay or roots		Corn		Wheat		Flax	
		Yield per acre	Cash value per acre	Yield per acre	Cash value per acre	Yield per acre	Cash value per acre	Yield per acre	Cash value per acre	Yield per acre	Cash value per acre
		Bu.		Tons		Bu.		Bu.		Bu.	
Wheat, hay, pasture, corn, oats	5	59.22	$19.66	2.54*	$16.65	55.98	$27.13	23.12	$20.61		
Wheat, hay, corn, oats	4	60.00	20.14	2.38	17.63	53.68	26.16	25.11	22.86		
Oats, wheat, corn, wheat, meadow, pasture, flax	7	53.75	18.50	2.55	17.09	53.43	26.05	22.49	19.86	17.42‡	$25.25
Oats, hay, potatoes, corn	4	51.35	17.88	2.73	20.16	52.85	25.74				
Oats, hay, potatoes	3	60.20	19.92	2.68	19.93						
Oats grown continuously		51.03	17.34								
Oats and wheat	2	55.29	18.74					21.82	19.38		
Wheat grown continuously								17.33	15.45		
Oats and corn	2	57.71	19.84			47.34	22.84				
Corn grown continuously						45.34	22.45				
Mangels grown continuously (6 tons manure)				14.88*	26.04						
Mangels grown continuously (12 tons manure)				17.72*	31.01						

* Five-year average.
‡ Two-year average.

TABLE XVII—*Continued*

SUMMARY OF YIELDS AND CASH VALUES—SYSTEMS-OF-CROPPING EXPERIMENT

System of cropping	Length in years	Yield and cash values by crops				All crops in each system			
		Potatoes		Pasture					
		Yield per acre	Cash value per acre	Yield per acre	Cash value per acre	Cash value per acre	Cost of production per acre	Net gain per acre	Increase + or decrease − compared with 5-year rotation
		Bu.		Mo.					
Wheat, hay, pasture, corn, oats	5			41.1†	$8.22	$19.59	$10.83	$8.76	
Wheat, hay, corn, oats	4					21.70	11.90	9.80	+$1.04
Oats, wheat, corn, wheat, meadow, pasture, flax	7			57.6†	11.52	19.96	10.90	9.06	+ 0.30
Oats, hay, potatoes, corn	4	106.53	$41.25			26.22	16.80	9.42	+ 0.66
Oats, hay, potatoes	3	99.99	38.95			23.27	17.89	5.38	− 3.38
Oats grown continuously						17.34	12.19	5.15	− 3.61
Oats and wheat	2					19.06	12.40	6.66	− 2.10
Wheat grown continuously						15.45	12.61	2.84	− 5.92
Oats and corn	2					21.34	12.50	8.84	− 0.08
Corn grown continuously						22.45	13.50	8.95	+ 0.19
Mangels grown continuously (6 tons manure)						26.04	32.68	−6.64	−15.40
Mangels grown continuously (12 tons manure)						31.01	32.68	−1.67	−10.43

† Three-year average.

COMMERCIAL FERTILIZER INVESTIGATIONS

Some preliminary work with commercial fertilizer had been done in Minnesota prior to 1909. Snyder reported the results of this work in Minnesota Bulletins 94[6] and 102[7], drawing the following conclusions: "Commercial fertilizers should not be used indiscriminately on old soils with a view of securing large yields, and it is not feasible by the use of commercial fertilizers alone to economically restore the fertility to soils that have been impoverished by exclusive cropping to small grains."[8]

Further work, covering several years, was needed to ascertain the value of the application of phosphorus, potash, and nitrogen in the form of commercial fertilizers, in a good rotation, where the supply of organic matter was kept up by applying moderate amounts of manure and by growing clover. The results of such a trial were of great interest in connection with the farm crops and farm management work. The experiment was therefore included with others planned by the Division of Agronomy and Farm Management.

TABLE XVIII

Plan of Fertilizing in Oats-Clover-Corn Rotation, Field T, Series VII, VIII, IX
Material—Amount per Acre Applied Each Year, and Cost

	To oats					To corn						Fertilizers in addition to barnyard manure in one cycle of rotation	
Plot	Acid phosphate	Rock phosphate	Muriate of potash	Nitrate of soda	Complete fertilizer	Acid phosphate	Rock phosphate	Muriate of potash	Nitrate of soda	Complete fertilizer	Stable manure	Amt. per acre	Cost* per acre
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	
9	125	.....	50	150	.....	125	.....	50	150	....	....	650	$14.75
10	.....	.....	.....	.....	.....	.....	1,000	....	....	......	12,000	1,000	4.75
11	200	.....	.....	.....	.....	200	.....	....	....	....	12,000	400	4.00
12	Check plot	.....	.....	.....	.....	.....	.....	....	....	....	12,000	....	....
13	.....	.....	100	.....	.....	.....	.....	100	....	....	12,000	200	5.00
14	.....	.....	.....	160	.....	.....	.....	....	160	....	12,000	320	10.40
15	.....	.....	.....	.....	250†	.....	.....	....	....	250†	12,000	500	8.46

*The fertilizers used are figured at the following prices per ton: Nitrate of soda, $65; muriate of potash, $50; acid phosphate, $20; rock phosphate, $9.50.

†Beginning in 1914, 200 pounds acid phosphate, 100 pounds muriate of potash, and 160 pounds nitrate of soda were applied to the oats and also to the corn.

METHODS

The form and the amounts of the different fertilizers applied in each of the three-year rotations, oats, clover, corn, including the standard three-year rotation, and the cost per acre are given in Table XVIII. With the exception of the rotation carried out on Plot 9 in each of the three series, manure was applied each year preceding the corn crop at the rate of 6 tons per acre. In each instance the clover sod was fall plowed for corn the succeeding year. The manure was applied on the fall-plowed land and disked in early in the spring. The oats were sown on double-disked and harrowed corn land.

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[6] Snyder, Harry. Soil investigations. Minn. Agr. Exp. Sta. Bull. 94, pp. 165-194. 1906.

[7] Snyder, Harry. Soil investigations. Minn. Agr. Exp. Sta. Bull. 102, pp. 1-38. 1907. These bulletins are now out of print.

[8] Bull. 94, p. 186.

THE STANDARD THREE-YEAR ROTATION

See Summary Table XXVI, page 44

The three-year rotation, oats, clover, corn, carried out on Plot 12 in each of the three series has proved to be one of the best. Six tons of manure per acre is applied preceding the corn crop. The rotation has yielded crops averaging $23.62 per acre, and an average net income of $11.95 per acre. This is a higher average value for the crops and a larger net income than was obtained from any rotation in the systems-of-cropping experiment. The yields and net income per acre are practically duplicated by the three-year rotation carried out on Plot 5 in each of the three series. Oats have lodged an average of 24 per cent during the period. Good stands of clover have been obtained each year with the exception of 1910. That year no stand of clover or timothy was obtained in any of the rotations in the experiments.

TABLE XIX

FERTILIZER EXPERIMENT

THREE-YEAR STANDARD ROTATION—OATS, HAY, CORN*

Yields and Cash Values by Plots

Year	Plot 12—Series VII			Plot 12—Series VIII			Plot 12—Series IX		
	Crop	Yield	Cash value	Crop	Yield	Cash value	Crop	Yield	Cash value
1909...	Oats, bu.....	74.68	$32.14	Corn, bu.....	79.23	$38.82	Hay, tons....	3.70	$22.20
1910...	Hay, tons....	0.85	7.74	Oats, bu.....	53.12	17.00	Corn, bu.....	36.96	16.63
1911...	Corn, bu.....	62.50	33.13	Hay, tons....	2.85	33.92	Oats, bu.....	39.37	15.75
1912...	Oats, bu.....	72.50	18.85	Corn, bu.....	43.83	16.22	Hay, tons....	1.87	11.97
1913...	Hay, tons....	3.17	20.92	Oats, bu.....	90.00	28.80	Corn, bu.....	63.36	33.58
1914...	Corn, bu.....	60.55	31.49	Hay, tons....	3.79	23.12	Oats, bu.....	56.56	22.62
Average...........		......	$24.05	....	......	$26.31	....	......	$20.46

Yields and Cash Values by Crops

Year	Oats		Hay		Corn	
	Yield	Cash value	Yield	Cash value	Yield	Cash value
	Bu.		Tons		Bu.	
1909....................	74.68	$32.14	3.70	$22.20	79.23	$38.82
1910....................	53.12	17.00	0.85	7.74	36.96	16.63
1911....................	39.37	15.75	2.85	33.92	62.50	33.13
1912....................	72.50	18.85	1.87	11.97	43.83	16.22
1913....................	90.00	28.80	3.17	20.92	63.36	33.58
1914....................	56.56	22.62	3.79	23.12	60.55	31.49
Average...............	64.37	$22.53	2.71	$19.98	57.74	$28.31

Average cash value of all crops in the rotation..................................	$23.62
Average cost of production per acre of all crops in the rotation....................	11.67
Average annual net gain per acre..	$11.95

* Six tons of manure per acre.

COMPLETE FERTILIZER ONLY

See Summary Table XXVI, page 44

It was the aim to supply in this rotation, in the form of commercial fertilizer, approximately the amount of nitrogen, phosphorus, and potash contained in 6 tons of average stable manure. The yields for the six-year period are practically the same as in the three-year standard rotation.

Adding to the average cost of production for the three crops, $14.75 for the fertilizer applied, makes the total cost of production per acre $26.42. The six-year average value per acre of the product was $22.96. This is a loss of $3.44 per acre where the complete commercial fertilizer was used instead of manure.

TABLE XX

THREE-YEAR ROTATION—OATS, HAY, CORN*—COMPLETE FERTILIZER ONLY

Yields and Cash Values by Plots

Year	Plot 9—Series VII			Plot 9—Series VIII			Plot 9—Series IX		
	Crop	Yield	Cash value	Crop	Yield	Cash value	Crop	Yield	Cash value
1909...	Oats, bu.....	70.62	$24.72	Corn, bu.....	68.66	$33.64	Hay, tons....	4.00	$24.00
1910...	Hay, tons....	1.25	11.38	Oats, bu.....	52.81	16.90	Corn, bu.....	42.91	19.31
1911...	Corn, bu.....	59.72	31.65	Hay, tons....	3.00	35.70	Oats, bu.....	45.60	18.24
1912...	Oats, bu.....	73.75	19.18	Corn, bu.....	46.76	17.30	Hay, tons....	1.77	11.33
1913...	Hay, tons....	2.07	13.66	Oats, bu.....	96.41	30.85	Corn, bu.....	59.48	31.52
1914...	Corn, bu.....	63.75	33.15	Hay, tons....	3.72	22.69	Oats, bu.....	46.25	18.50
Average...........		......	$22.29	....	......	$26.18	....	......	$20.48

Yields and Cash Values by Crops

Year	Oats		Hay		Corn	
	Yield	Cash value	Yield	Cash value	Yield	Cash value
	Bu.		Tons		Bu.	
1909....................	70.62	$24.72	4.00	$24.00	68.66	$33.64
1910....................	52.81	16.90	1.25	11.38	42.91	19.31
1911....................	45.60	18.24	3.00	35.70	59.72	31.65
1912....................	73.75	19.18	1.77	11.33	46.76	17.30
1913....................	96.41	30.85	2.07	13.66	59.48	31.52
1914....................	46.25	18.50	3.72	22.69	63.75	33.15
Average...............	64.24	$21.40	2.64	$19.79	56.88	$27.76

Average cash value per acre of all crops in the rotation............................	$22.98
Average cost of production per acre of all crops in the rotation......................	26.42
Average annual net loss per acre..	3.44†

* Acid phosphate 250 pounds, sodium nitrate 300 pounds, muriate of potash 100 pounds per acre, one half applied to corn and one half to oats.

† No allowance has been made for whatever difference there may be in the cost per acre of applying six tons of manure as compared with 650 pounds of commercial fertilizer.

On the majority of Minnesota farms, manure is a by-product which has no market value and the only charge which must be made against a crop to which manure is applied is the actual cost of the application. This is approximately 32 cents per ton.[9] Considered from this standpoint, the results show clearly that the use of stable manure is to be preferred, as compared with commercial fertilizers only. It is to be expected that the application of manure will show more favorable results as compared with the commercial fertilizer alone in the second period of the experiment than in the first. More exhaustive experiments at University Farm and various substations have been started.

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[9] Peck, F. W. The cost of producing Minnesota farm products; field crops; 1908-1912. Minn. Agr. Exp. Sta. Bull. 145, pp. 1-48. 1914.

RAW PHOSPHATE ROCK

See Summary Table XXVI, page 44

In the six-year period there have been two applications of 1,000 pounds per acre of raw phosphate rock in addition to the manure to each plot in the rotation carried out on Plot 10 in each of the three series. The slight increases in yields, when compared with those obtained in the standard three-year rotation, are within the limits of experimental error. The lodging of the grain averaged 60 per cent more than in the standard three-year rotation. The net income is $7.36 per acre as compared with $11.95 for the standard three-year rotation where manure only was applied. There was a loss at the rate of $4.59 per acre when raw phosphate rock was used in addition to the manure.

TABLE XXI

THREE-YEAR ROTATION—OATS, HAY, CORN*—RAW PHOSPHATE ROCK

Yields and Cash Values by Plots

Year	Plot 10—Series VII			Plot 10—Series VIII			Plot 10—Series IX		
	Crop	Yield	Cash value	Crop	Yield	Cash value	Crop	Yield	Cash value
1909...	Oats, bu.....	84.37	$29.53	Corn, bu......	72.93	$35.74	Hay, tons....	3.90	$23.40
1910...	Hay, tons....	0.95	8.65	Oats, bu.....	55.93	17.90	Corn, bu.....	43.28	19.48
1911...	Corn, bu.....	61.11	32.39	Hay, tons....	2.90	34.51	Oats, bu.....	38.70	15.48
1912...	Oats, bu.....	63.13	16.41	Corn, bu.....	48.44	17.92	Hay, tons....	1.85	11.84
1913...	Hay, tons....	3.43	22.64	Oats, bu.....	93.44	29.90	Corn, bu.....	62.74	33.25
1914...	Corn, bu.....	62.50	32.50	Hay, tons....	4.09	24.95	Oats, bu.....	54.06	21.62
Average...........	....	......	$23.69	....	......	$26.82	....	......	$20.85

Yields and Cash Values by Crops

Year	Oats		Hay		Corn	
	Yield	Cash value	Yield	Cash value	Yield	Cash value
	Bu.		Tons		Bu.	
1909....................	84.37	$29.53	3.90	$23.40	72.93	$35.74
1910....................	55.93	17.90	0.95	8.65	43.28	19.48
1911....................	38.70	15.48	2.90	34.51	61.11	32.39
1912....................	63.13	16.41	1.85	11.84	48.44	17.92
1913....................	93.44	29.90	3.43	22.64	62.74	33.25
1914....................	54.06	21.62	4.09	24.95	62.50	32.50
Average..............	64.94	$21.81	2.85	$21.00	58.50	$28.55

Average cash value per acre of all crops in the rotation..............................	$23.78
Average cost of production per acre of all crops in the rotation including $4.75 for 1,000 pounds raw phosphate rock..	16.42
Average annual net gain per acre..	$7.36

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* Six tons of manure per acre.

ACID PHOSPHATE

See Summary Table XXVI, page 44

The differences in yields in the rotation on Plot 11 in each of the three series where acid phosphate was applied, 200 pounds per acre to the corn and 200 pounds to the oats in addition to manure, as compared with those of the standard three-year rotation, are well within the limits of experimental error. The lodging of the grain was 4 per cent greater than in the standard three-year rotation. The application of 400 pounds of acid phosphate per acre, costing $4, gave very slight increase in yield for the six-year period and reduced the net income per acre to $8.18, as compared with $11.95 on the standard three-year rotation. There was a loss at the rate of $3.77 per acre where acid phosphate was applied.

TABLE XXII

THREE-YEAR ROTATION—OATS, HAY, CORN*—ACID PHOSPHATE

Yields and Cash Values by Plots

Year	Plot 11—Series VII			Plot 11—Series VIII			Plot 11—Series IX		
	Crop	Yield	Cash value	Crop	Yield	Cash value	Crop	Yield	Cash value
1909	Oats, bu	76.87	$26.90	Corn, bu	76.07	$37.27	Hay, tons	3.90	$23.40
1910	Hay, tons	1.05	9.56	Oats, bu	53.12	17.00	Corn, bu	39.23	17.65
1911	Corn, bu	63.88	33.86	Hay, tons	2.85	33.92	Oats, bu	44.68	17.87
1912	Oats, bu	76.25	19.83	Corn, bu	46.08	17.05	Hay, tons	1.96	12.54
1913	Hay, tons	3.38	21.21	Oats, bu	93.44	29.90	Corn, bu	63.19	33.49
1914	Corn, bu	60.28	31.35	Hay, tons	4.29	26.17	Oats, bu	50.63	20.25
Average			$23.79			$26.89			$20.87

Yields and Cash Values by Crops

Year	Oats		Hay		Corn	
	Yield	Cash value	Yield	Cash value	Yield	Cash value
	Bu.		Tons		Bu.	
1909	76.87	$26.90	3.90	$23.40	76.07	$37.27
1910	53.12	17.00	1.05	9.56	39.23	17.65
1911	44.68	17.87	2.85	33.92	63.88	33.86
1912	76.25	19.83	1.96	12.54	46.08	17.05
1913	93.44	29.90	3.38	21.21	63.19	33.49
1914	50.63	20.35	4.29	26.17	60.28	31.35
Average	65.83	$21.96	2.91	$21.13	58.12	$28.45

Average cash value of all crops in the rotation	$23.85
Average cost of production of all crops, including $4 for 400 pounds acid phosphate per acre	$15.67
Average annual net gain per acre	$8.18

* Six tons of manure per acre.

MURIATE OF POTASH

See Summary Table XXVI, page 44

In the rotation in which muriate of potash was applied each year in addition to the manure, 100 pounds per acre was used on the oats and also on the corn. The cost of 200 pounds of muriate of potash was $5. The increase in yields above those obtained in the three-year standard rotation was so slight as to be well within the limits of experimental error. The potash showed a marked tendency to strengthen the straw of the oats. The average percentage of lodging was 12 as compared with 24 for the three-year standard rotation. The grain ripened from three days to a week earlier than in the three-year standard rotation. No difference in the time of maturity of the corn crop was noted. The use of muriate of potash reduced the net gain per acre to $7.12 as compared with $11.95 for the three-year standard rotation. There was a loss of $4.83 per acre where muriate of potash was applied.

TABLE XXIII

THREE-YEAR ROTATION—OATS, HAY, CORN*—MURIATE OF POTASH

Yields and Cash Values by Plots

Year	Plot 13—Series VII			Plot 13—Series VIII			Plot 13—Series IX		
	Crop	Yield	Cash value	Crop	Yield	Cash value	Crop	Yield	Cash value
1909...	Oats, bu.....	75.93	$26.58	Corn, bu.....	70.32	$34.46	Hay, tons....	3.45	$20.70
1910...	Hay, tons....	1.15	10.47	Oats, bu.....	49.68	15.90	Corn, bu.....	42.64	19.19
1911...	Corn, bu.....	68.05	36.07	Hay, tons....	3.00	35.70	Oats, bu.....	47.50	19.00
1912...	Oats, bu.....	78.44	20.39	Corn. bu.....	50.25	18.59	Hay, tons....	1.67	9.69
1913...	Hay, tons....	3.14	20.72	Oats, bu.....	85.31	27.30	Corn, bu.....	62.84	33.31
1914...	Corn, bu.....	65.56	34.09	Hay, tons....	3.75	22.88	Oats, bu.....	55.31	22.12
Average...........		......	$24.89	....	......	$25.81	....	......	$20.67

Yields and Cash Values by Crops

Year	Oats		Hay		Corn	
	Yield	Cash value	Yield	Cash value	Yield	Cash value
	Bu.		Tons		Bu.	
1909....................	75.93	$26.58	3.45	$20.70	70.32	$34.46
1910....................	49.68	15.90	1.15	10.47	42.64	19.19
1911....................	47.50	19.00	3.00	35.70	68.05	36.07
1912....................	78.44	20.39	1.67	9.69	50.25	18.59
1913....................	85.31	27.30	3.14	20.72	62.84	33.31
1914....................	55.31	22.12	3.75	22.88	65.56	34.09
Average...............	65.36	$23.55	2.69	$20.03	59.94	$29.29

Average cash value per acre of all crops in the rotation..............................	$23.79
Average cost of production per acre of all crops in the rotation, including $5 for 200 pounds muriate of potash..	16.67
Average annual net gain per acre..	$7.12

* Six tons of manure per acre.

NITRATE OF SODA

·See Summary Table XXVI, page 44

On Plot 14 in each of the three series in the rotation, oats, clover, corn, nitrate of soda was applied annually to the oats and corn at the rate of 160 pounds per acre. Comparison of the yields obtained in this rotation with those of the three-year standard rotation shows a slightly lower yield of oats, due largely to the high percentage of lodging, an average of 53 per cent as compared with 24 per cent in the three-year standard. The lodging has taken place early in the season. In 1914 rust was very much in evidence. The severe lodging of the oats has brought about a poor stand of clover and timothy five years out of six. This has reduced the yields of the hay crops below those in the three-year standard rotation. In 1910 no lodging took place on account of the extreme drouth, but the stand of clover and timothy was lost completely, as it was in all the other rotations.

There is a very moderate but consistent increase in the corn yields five years out of six over those in the three-year standard rotation.

The six-year average cash value per acre of the three crops in the rotation is lower than for the three-year standard rotation. Deducting the cost of producing the crop, including $10.40 for 320 pounds of nitrate of soda, there is a net income per acre of 58 cents as compared with $11.95 from the three-year standard rotation. Compared with the three-year standard rotation there was a loss of $11.37 per acre where nitrate of soda was applied.

TABLE XXIV

THREE-YEAR ROTATION—OATS, HAY, CORN*—NITRATE OF SODA
Yields and Cash Values by Plots

Year	Plot 14—Series VII			Plot 14—Series VIII			Plot 14—Series IX		
	Crop	Yield	Cash value	Crop	Yield	Cash value	Crop	Yield	Cash value
1909...	Oats, bu.....	67.81	$23.73	Corn, bu.....	75.46	$36.98	Hay, tons....	3.80	$22.80
1910...	Hay, tons....	1.30	11.83	Oats, bu.....	52.81	16.90	Corn, bu.....	45.94	20.67
1911...	Corn, bu.....	65.27	34.59	Hay, tons....	2.35	27.97	Oats, bu.....	40.93	16.37
1912...	Oats, bu.....	77.81	20.23	Corn, bu.....	46.77	17.30	Hay, tons....	1.99	12.74
1913...	Hay, tons....	2.53	16.70	Oats, bu.....	101.56	32.50	Corn, bu.....	64.04	33.94
1914...	Corn, bu.....	63.61	33.08	Hay, tons....	3.81	23.24	Oats, bu.....	40.63	16.25
Average............		......	$23.33	....	......	$25.62	....	......	$18.78

Yields and Cash Values by Crops

Year	Oats		Hay		Corn	
	Yield	Cash value	Yield	Cash value	Yield	Cash value
	Bu.		Tons		Bu.	
1909....................	67.81	$23.73	3.80	$22.80	75.46	$36.98
1910....................	52.81	16.90	1.30	11.83	45.94	20.67
1911....................	40.93	16.37	2.35	27.97	65.27	34.59
1912....................	77.81	20.23	1.99	12.74	46.77	17.30
1913....................	101.56	32.50	2.53	16.70	64.04	33.94
1914....................	40.63	16.25	3.81	23.24	63.61	33.08
Average.................	63.59	$20.99	2.63	$19.21	60.18	$29.42

Average cash value per acre of all crops in the rotation..............................	$22.65
Average cost of production per acre of all crops in the rotation, including $10.40 per acre for 320 pounds of nitrate of soda..............................	22.07
Average annual net gain per acre..............................	$0.58

* Six tons of manure per acre.

Nitrogen can easily be added to the soil by growing leguminous crops, pasturing them off or feeding them in the form of hay and returning the manure to the soil, or by plowing under an occasional crop.

Therefore there is little reason to believe that any of its commercial forms can be used with profit in producing the ordinary farm crops.

COMPLETE COMMERCIAL FERTILIZER AND MANURE

See Summary Table XXVI, page 44

The application of a complete commercial fertilizer in addition to the manure as applied in the standard three-year rotation did not increase yields. The lodging averaged 39 per cent as compared with 24 per cent in the standard three-year rotation. The stands of clover and timothy were relatively poor, for which the early lodging of the oat crop has been largely responsible.

Altho the six-year average cash value per acre of the crops with this treatment is nearly equal to that of the three-year standard rotation, the cost of the fertilizer, $8.40 per acre, reduces the net income to $3.11 as compared with $11.95 for the standard three-year rotation.

TABLE XXV

Three-Year Rotation—Oats, Clover, Corn*—Complete Fertilizer†

Yields and Cash Values by Plots

Year	Plot 15—Series VII			Plot 15—Series VIII			Plot 15—Series IX		
	Crop	Yield	Cash value	Crop	Yield	Cash value	Crop	Yield	Cash value
1909...	Oats, bu.....	74.37	$26.03	Corn, bu.....	71.05	$34.81	Hay, tons....	3.55	$21.30
1910...	Hay, tons....	1.10	10.01	Oats, bu.....	51.25	16.40	Corn, bu.....	45.57	20.51
1911...	Corn, bu.....	55.55	29.44	Hay, tons....	3.25	38.67	Oats, bu.....	47.18	18.87
1912...	Oats, bu.....	77.50	20.15	Corn, bu.....	37.36	13.82	Hay, tons....	1.67	9.69
1913...	Hay, tons....	3.03	20.00	Oats, bu.....	97.19	31.10	Corn, bu.....	63.76	33.79
1914...	Corn, bu.....	61.81	32.14	Hay, tons....	3.88	23.67	Oats, bu.....	45.00	18.00
Average.............		......	$22.96	....	......	$26.41	....	......	$20.36

Yields and Cash Values by Crops

Year	Oats		Hay		Corn	
	Yield	Cash value	Yield	Cash value	Yield	Cash value
	Bu.		Tons		Bu.	
1909....................	74.37	$26.03	3.55	$21.30	71.05	$34.81
1910....................	51.25	16.40	1.10	10.01	45.57	20.51
1911....................	47.18	18.87	3.25	38.67	55.55	29.44
1912....................	77.50	20.15	1.67	9.69	37.36	13.82
1913....................	97.19	31.10	3.03	20.00	63.76	33.79
1914....................	45.00	18.00	3.88	23.67	61.81	32.14
Average.................	65.42	$21.76	2.75	$20.56	55.85	$27.42

Average cash value of all crops in the rotation....................................	$23.24
Average cost of production per acre, including $8.46 per acre for fertilizer............	20.13
Average annual net gain per acre..	$3.11

* Six tons of manure per acre.

† 500 pounds complete fertilizer per acre, one half to oats and one half to corn. In 1914 and thereafter, 400 pounds acid phosphate, 200 pounds muriate of potash, and 320 pounds nitrate of soda per acre, were applied.

There was a loss at the rate of $8.84 per acre where a complete commercial fertilizer was applied.

RESULTS FROM THE USE OF COMMERCIAL FERTILIZERS

1. The three-year standard rotation, oats, clover hay, corn, with 6 tons of manure per acre applied preceding the corn crop, gave net returns at the rate of $11.95 per acre for the six-year period. No charge was made for the manure other than the cost of application.

2. The application of a complete commercial fertilizer instead of manure gave practically the same yields as were obtained in the standard three-year rotation. Charging the cost of the commercial fertilizer against the crops, there was a loss per acre of $3.44.

3. Raw phosphate rock applied at the rate of 1,000 pounds per acre preceding corn did not appreciably increase the yields over those of the three-year standard rotation. There was a loss of $4.59 per acre when raw rock phosphate was used.

4. The use of acid phosphate at the rate of 400 pounds per acre resulted in a loss of $3.77 per acre.

TABLE XXVI

SUMMARY OF AVERAGE YIELDS AND CASH VALUES—FERTILIZER EXPERIMENT, 1909-1914
THREE-YEAR ROTATION—OATS, HAY, CORN

Plot	Fertilizer	Amt. per acre	Cost per acre	Yields and Cash Values by Crops					
				Oats		Hay		Corn	
				Yield per acre	Cash value per acre	Yield per acre	Cash value per acre	Yield per acre	Cash value per acre
		Lbs.		Bu.		Tons		Bu.	
12	Check(No application) ..	....	....	64.37	$22.53	2.71	$19.98	57.74	$28.31
9	Acid phosphate......... Muriate of potash....... Nitrate of soda.........	250 100 300	$14.75	64.24	21.40	2.64	19.79	56.88	27.76
10	Raw phosphate rock.....	1,000	4.75	64.94	21.81	2.85	21.00	58.50	28.55
11	Acid phosphate.........	400	4.00	65.83	21.96	2.91	21.13	58.12	28.45
13	Muriate of potash.......	200	5.00	65.36	23.55	2.69	20.03	59.94	29.29
14	Nitrate of soda.........	320	10.40	63.59	20.99	2.63	19.21	60.18	29.42
15	Complete fertilizer†......	500	8.46	65.42	21.76	2.75	20.56	55.85	27.42

Plot	Fertilizer	All Crops in Each Rotation			
		Cash value per acre	Cost of production per acre	Net gain per acre	Increase+or decrease—compared with check
12	Check (No application)....	$23.62	$11.67	$11.95	....
9	Acid phosphate.......... Muriate of potash........ Nitrate of soda..........	22.98	12.62	10.36*	—$1.59*
10	Raw phosphate rock.......	23.78	16.42	7.36	— 4.59
11	Acid phosphate...........	23.85	15.67	8.18	— 3.77
13	Muriate of potash.........	23.79	16.67	7.12	— 4.83
14	Nitrate of soda...........	22.65	22.07	0.58	—11.37
15	Complete fertilizer†.......	23.24	20.13	3.11	— 8.84

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* No charge has been made for the manure other than the cost of application in any of the other rotations on Field T. No manure was applied in this rotation.

† Beginning in 1914, 200 pounds acid phosphate, 100 pounds muriate of potash, and 160 pounds nitrate of soda were applied to the oats and also to the corn.

5. The application of 200 pounds per acre of muriate of potash resulted in a loss of $4.83 per acre.

6. Nitrate of soda applied at the rate of 320 pounds per acre resulted in a loss of $11.37 per acre.

7. The application of a complete fertilizer in addition to manure resulted in a loss of $8.84 per acre.

8. The results of the experiments with commercial fertilizers in a three-year rotation, oats, clover, corn, covering a period of six years in which phosphorus, potash, and nitrogen were applied singly and together in addition to manure, show no marked and consistent increase in yields in any instance.

TILLAGE AND MANURING INVESTIGATIONS

Methods in tillage are governed somewhat by the character of the soil, its condition, and the season. For a brief description of the soil on which these experiments were carried out see page 10. As already stated, the methods of tillage in the three-year standard rotation are fall plowing of the meadow for corn, and double disking of the corn land for oats. When corn land is either fall plowed or spring plowed for oats, it is double disked and harrowed in the spring.

THE THREE-YEAR STANDARD ROTATION

See Summary Table XXXV, page 54

The three-year standard rotation carried out on Plot 5 in each of the three series is identical with the one carried on Plot 12, Series VII, VIII, and IX. There is considerable variation in yields for the different years, but the average yields of the two three-year standard rotations for the six-year period are very similar. The net income per acre is $11.89 and $11.95 respectively.

TABLE XXVII

THREE-YEAR STANDARD ROTATION—OATS, HAY, CORN*

Yields and Cash Values by Plots

Year	Plot 5—Series VII			Plot 5—Series VIII			Plot 5—Series IX		
	Crop	Yield	Cash value	Crop	Yield	Cash value	Crop	Yield	Cash value
1909...	Oats, bu.....	78.75	$27.56	Corn, bu.....	70.50	$34.55	Hay, tons....	4.00	$24.00
1910...	Hay, tons....	1.20	10.92	Oats, bu.....	47.18	15.10	Corn, bu.....	42.18	18.98
1911...	Corn, bu.....	66.66	35.33	Hay, tons....	2.95	35.11	Oats, bu.....	55.00	22.00
1912...	Oats, bu.....	44.06	11.46	Corn, bu.....	49.58	18.34	Hay, tons....	2.28	14.59
1913...	Hay, tons....	2.93	19.34	Oats, bu.....	92.81	29.70	Corn, bu.....	56.93	30.17
1914...	Corn, bu.....	61.67	32.07	Hay, tons....	3.98	24.28	Oats, bu.....	51.56	20.62
Average...........		......	$22.78	....	......	$26.18	....	......	$21.73

Yields and Cash Values by Crops

Year	Oats		Hay		Corn	
	Yield	Cash value	Yield	Cash value	Yield	Cash value
	Bu.		Tons		Bu.	
1909..................	78.75	$27.56	4.00	$24.00	70.50	$34.55
1910..................	47.18	15.10	1.20	10.92	42.18	18.98
1911..................	55.00	22.00	2.95	35.11	66.66	35.33
1912..................	44.06†	11.46	2.28	14.59	49.58	18.34
1913..................	92.81	29.70	2.93	19.34	56.93	30.17
1914..................	51.56	20.62	3.98	24.28	61.67	32.07
Average...............	61.56	$21.07	2.89	$21.37	57.92	$28.24

Average cash value per acre of all crops in the rotation...........................	$23.56
Average cost of production per acre of all crops in the rotation......................	11.67
Average annual net gain per acre..	$11.89

* Six tons of manure per acre.

† 60 per cent lodged.

ROTATION WITHOUT MANURE

See Summary Table XXXV, page 54

No manure has been applied to the corn in the three-year rotation carried out on Plot 4, in each of the three series. With this exception it is identical with the three-year standard rotation. Compared with the three-year standard rotation, the average yields of oats and hay do not show any marked tendency either way. During the last part of the six-year period in the rotation receiving no application of manure, the corn showed a tendency toward lowering in yield. The four-year average yields of corn are 51.24 and 58.71 bushels respectively, or 7.47 bushels in favor of the three-year standard rotation. Making no charge for the manure applied in the three-year standard rotation other than the cost of hauling, there is a difference in the net income for the six-year period of 55 cents per acre in favor of no manure. As already stated, the soil at the beginning of the experiment was well supplied with organic matter. The residue of the clover crop grown every third year tended to make the reduction of the total amount of organic matter gradual.

TABLE XXVIII
THREE-YEAR ROTATION—OATS, HAY, CORN—NO MANURE OR FERTILIZER
Yields and Cash Values by Plots

Year	Plot 4—Series VII			Plot 4—Series VIII			Plot 4—Series IX		
	Crop	Yield	Cash value	Crop	Yield	Cash value	Crop	Yield	Cash value
1909...	Oats, bu.....	75.93	$26.58	Corn, bu.....	62.01	$30.38	Hay, tons....	4.20	$25.20
1910...	Hay, tons....	1.00	9.10	Oats, bu.....	52.81	16.90	Corn, bu.....	48.21	21.69
1911...	Corn, bu.....	54.86	29.08	Hay, tons....	2.85	33.92	Oats, bu.....	52.50	21.00
1912...	Oats, bu.....	43.75	11.38	Corn, bu.....	44.34	16.41	Hay, tons....	2.14	13.69
1913...	Hay, tons....	2.74	18.08	Oats, bu.....	85.63	27.40	Corn, bu.....	54.15	28.70
1914...	Corn, bu.....	51.67	26.87	Hay, tons....	3.52	21.47	Oats, bu.....	54.06	21.62
Average...........	......	......	$20.18	....	......	$24.41	....	......	$21.98

Yields and Cash Values by Crops

Year	Oats		Hay		Corn	
	Yield	Cash value	Yield	Cash value	Yield	Cash value
	Bu.		Tons		Bu.	
1909....................	75.93	$26.58	4.20	$25.20	62.01	$30.38
1910....................	52.81	16.90	1.00	9.10	48.21	21.69
1911....................	52.50	21.00	2.85	33.92	54.86	29.08
1912....................	43.75	11.38	2.14	13.69	44.34	16.41
1913....................	85.63	27.40	2.74	18.08	54.15	28.70
1914....................	54.06	21.62	3.52	21.47	51.67	26.87
Average..............	60.78	$20.81	2.74	$20.24	52.54	$25.52

Average cash value per acre of all crops in the rotation..............................	$22.19
Average cost per acre of producing all crops in the rotation, deducting the cost of applying 6 tons of manure at 32 cents per ton....................................	9.75*
Average annual net gain per acre..	$12.44

* Since no manure is applied to the corn in this rotation, the cost of production of that crop is lessened by $1.92, the cost of applying six tons of manure at 32 cents per ton.

MANURE APPLIED TO MEADOW

See Summary Table XXXV, page 54

In the rotation carried out on Plot 7 in each of the three series, the manure is applied to the meadow in the spring instead of preceding the corn, as in the three-year standard rotation. In comparison with the three-year standard rotation, for the six-year period, there is no consistent advantage in yields of hay in favor of applying the manure to the meadow. With the exception of 1913, there is a small but consistent increase in the yield of corn in favor of applying the manure directly to this crop as is done in the three-year standard rotation. The six-year average cash value and net income per acre are not widely different from those in the three-year standard rotation. As far as could be observed, the lodging of the oats was as serious where the manure was applied preceding the meadow as in the three-year standard rotation where it was applied preceding the corn crop.

TABLE XXIX

THREE-YEAR ROTATION—OATS, HAY*, CORN—MANURE APPLIED TO MEADOW

Yields and Cash Values by Plots

Year	Plot 7—Series VII			Plot 7—Series VIII			Plot 7—Series IX		
	Crop	Yield	Cash value	Crop	Yield	Cash value	Crop	Yield	Cash value
1909...	Oats, bu.....	69.37	$24.28	Corn, bu.....	67.57	$33.11	Hay, tons....	4.15	$24.90
1910...	Hay, tons....	1.00	9.10	Oats, bu.....	48.75	15.60	Corn, bu.....	39.96	17.98
1911...	Corn, bu.....	54.86	29.08	Hay, tons....	2.85	33.92	Oats, bu.....	52.50	21.00
1912...	Oats, bu.....	76.25	19.83	Corn, bu.....	48.86	18.08	Hay, tons....	1.56	9.98
1913...	Hay, tons....	3.06	20.20	Oats, bu.....	91.88	29.40	Corn, bu.....	58.68	31.10
1914...	Corn, bu.....	57.92	30.12	Hay, tons....	4.64	28.30	Oats, bu.....	55.62	22.25
Average...........		......	$22.10	....	......	$26.40	....	......	$21.20

Yields and Cash Values by Crops

Year	Oats		Hay		Corn	
	Yield	Cash value	Yield	Cash value	Yield	Cash value
	Bu.		Tons		Bu.	
1909....................	69.37	$24.28	4.15	$24.90	67.57	$33.11
1910....................	48.75	15.60	1.00	9.10	39.96	17.98
1911....................	52.50	21.00	2.85	33.92	54.86	29.08
1912....................	76.25	19.83	1.56	9.98	48.86	18.09
1913....................	91.88	29.40	3.06	20.20	58.68	31.10
1914....................	55.62	22.25	4.64	28.30	57.92	30.12
Average...............	65.73	$22.06	2.88	$21.07	54.64	$26.58

Average cash value per acre of all crops in the rotation..............................	$23.23
Average cost of production per acre of all crops in the rotation......................	11.67
Average annual net gain per acre..	$11.56

* Six tons of manure per acre.

GRASS PASTURED OFF

See Summary Table XXXV, page 54

The grass in the rotation on Plot 8, in each of the three series, was pastured off instead of removing it for hay, as is the practice in the three-year standard rotation. The yields have been variable but show a tendency during the latter part of the six-year period toward higher yields of corn than in the three-year standard rotation. The six-year average cash value of the crops in this rotation and the net income per acre are lower by $2.37 than in the three-year standard rotation.

Lodging of the oats occurred earlier in the season than in the three-year standard rotation, but did not affect the yields more seriously during the six-year period.

On lands deficient in organic matter and nitrogen, growing leguminous crops and pasturing them off is one of the best methods of increasing both the yields and net profits per acre from the corn and grain crops.

TABLE XXX

THREE-YEAR ROTATION—OATS, HAY, CORN*—GRASS PASTURED OFF

Yields and Cash Values by Plots

Year	Plot 8—Series VII			Plot 8—Series VIII			Plot 8—Series IX		
	Crop	Yield	Cash value	Crop	Yield	Cash value	Crop	Yield	Cash value
1909...	Oats, bu.....	73.12	$25.59	Corn, bu.....	46.00	$22.54	Pasture, mo..	......	......
1910...	Pasture, mo..	......	......	Oats, bu.....	51.87	16.60	Corn, bu.....	44.55	$20.05
1911...	Corn, bu.....	63.88	33.86	Pasture, mo..	......	......	Oats, bu.....	45.00	18.00
1912...	Oats, bu.....	75.93	19.74	Corn, bu.....	50.75	18.78	Pasture, mo..	37.00	7.40
1913...	Pasture, mo..	58.50	11.70	Oats, bu.....	95.63	30.60	Corn, bu.....	62.79	33.28
1914...	Corn, bu.....	64.16	33.36	Pasture, mo..	58.33	11.67	Oats, bu.....	41.88	16.75
Average...........		......	$24.85	....	......	$20.04	....	......	$19.10

Yields and Cash Values by Crops

Year	Oats		Pasture		Corn	
	Yield	Cash value	Yield	Cash value	Yield	Cash value
	Bu.		Mo.		Bu.	
1909....................	73.12	$25.59	....	....	46.00	$22.54
1910....................	51.87	16.60	....	....	44.55	20.05
1911....................	45.00	18.00	....	....	63.88	33.86
1912....................	75.93	19.74	37.00	$7.40	50.75	18.78
1913....................	95.63	30.60	58.50	11.70	62.79	33.28
1914....................	41.88	16.75	58.33	11.67	64.16	33.36
Average...............	63.91	$21.21	51.71	$10.26†	55.34	$26.98

Average cash value per acre of all crops in the rotation..........................	$19.48
Average cost of production per acre of all crops in the rotation.....................	10.21
Average annual net gain per acre...	$9.27

* Six tons of manure per acre.

† Three-year average.

SPRING PLOWING FOR CORN

See Summary Table XXXV, page 54

In the rotation carried out on Plot 6, in each of the three series, the ground for the corn has been plowed each spring as near the middle of April as possible. The further preparation of the seedbed for corn is double disking and harrowing the same as in the three-year standard rotation.

For no apparent reason the yields of oats and corn are decidedly lower the first year of the rotation on Plot 6 than on Plot 5 in each series. Not considering the results for the first year, comparison shows that each year the yields of corn on the spring-plowed ground equal those in the three-year standard rotation, or surpass them.

In 1910, a year of extreme drouth, the corn on the spring-plowed ground yielded somewhat higher than on the fall-plowed ground. Oats showed approximately the same difference.

The results for the last five years indicate that on this black silt loam soil there is little choice between fall and early spring plowing for corn. However, if plowing for corn is left until spring, on account of the pressure of other work it is usually left until about planting-time. The results of this experiment should not be taken to indicate that late spring plowing is equal to fall plowing for the corn crop. Fall plowing of old meadows or pastures for corn is always preferable to spring plowing, as it aids in controlling cutworms.

TABLE XXXI

THREE-YEAR ROTATION—OATS, HAY, CORN*—SPRING PLOWING FOR CORN

Yields and Cash Values by Plots

Year	Plot 6—Series VII			Plot 6—Series VIII			Plot 6—Series IX		
	Crop	Yield	Cash value	Crop	Yield	Cash value	Crop	Yield	Cash value
1909...	Oats, bu.....	71.56	$25.05	Corn, bu.....	55.15	$27.02	Hay, tons....	4.10	$24.60
1910...	Hay, tons....	1.45	13.20	Oats, bu.....	49.37	15.80	Corn, bu.....	45.55	20.50
1911...	Corn, bu.....	65.97	34.96	Hay, tons....	3.20	38.08	Oats, bu.....	57.18	22.87
1912...	Oats, bu.....	66.50	17.29	Corn, bu.....	49.18	18.20	Hay, tons....	1.83	11.71
1913...	Hay, tons....	3.20	21.12	Oats, bu.....	85.94	27.50	Corn, bu.....	63.64	33.73
1914...	Corn, bu.....	63.61	33.08	Hay, tons....	4.12	25.13	Oats, bu.....	52.19	20.88
Average...........		......	$24.12	....	......	$25.29	....	......	$22.38

Yields and Cash Values by Crops

Year	Oats		Hay		Corn	
	Yield	Cash value	Yield	Cash value	Yield	Cash value
	Bu.		Tons		Bu.	
1909....................	71.56	$25.05	4.10	$24.60	55.15	$27.02
1910....................	49.37	15.80	1.45	13.20	45.55	20.50
1911....................	57.18	22.87	3.20	38.08	65.97	34.96
1912....................	66.50	17.29	1.83	11.71	49.18	18.20
1913....................	85.94	27.50	3.20	21.12	63.64	33.73
1914....................	52.19	20.88	4.12	25.13	63.61	33.08
Average..............	63.79	$21.57	2.98	$22.31	57.18	$27.92

Average cash value per acre of all crops in the rotation..............................	$23.93
Average cost of production per acre of all crops in the rotation......................	11.67
Average annual net gain per acre..	$12.26

* Six tons of manure per acre.

FALL PLOWING FOR OATS

See Summary Table XXXV, page 54

In the rotation carried out on Plot 3, in each of the three series, the corn ground is fall plowed for oats the following year. In the spring it is given the same treatment as the ground for corn in the three-year standard rotation. This makes an additional charge of $1.50 per acre against the oats raised on fall-plowed double-disked corn land, as compared with that in the three-year standard rotation where the corn ground is double disked only for this crop.

The yields of oats as compared with those in the three-year standard rotation are well within the limits of experimental error. In the two rotations, the yields of hay and corn are very similar.

In 1910, the year of extreme drouth, the oats grown on fall-plowed ground gave the higher yield. The amount of lodging has been as great as in the three-year standard rotation, but the reduction in yield due to this cause has been somewhat less. The yields of hay are very similar. This confirms the opinion that the stands of clover and timothy have been as good as those in the three-year standard rotation where the oats is sown on double-disked corn land.

TABLE XXXII

THREE-YEAR ROTATION—OATS, HAY, CORN*—FALL PLOWING FOR OATS

Yields and Cash Values by Plots

Year	Plot 3—Series VII			Plot 3—Series VIII			Plot 3—Series IX		
	Crop	Yield	Cash value	Crop	Yield	Cash value	Crop	Yield	Cash value
1909...	Oats, bu.....	67.81	$23.73	Corn, bu.....	67.08	$32.87	Hay, tons....	4.10	$24.60
1910...	Hay, tons....	1.35	12.29	Oats, bu.....	50.93	16.30	Corn, bu.....	47.18	21.23
1911...	Corn, bu.....	56.94	30.18	Hay, tons....	2.90	34.51	Oats, bu.....	46.25	18.50
1912...	Oats, bu.....	78.44	20.39	Corn, bu.....	48.43	17.92	Hay, tons....	1.76	11.26
1913...	Hay, tons....	2.92	19.27	Oats, bu.....	91.88	29.40	Corn, bu.....	58.20	30.85
1914...	Corn, bu.....	60.00	31.20	Hay, tons....	4.09	24.95	Oats, bu.....	46.56	18.62
Average...........		......	$22.84	....	......	$25.99	....	......	$20.84

Yields and Cash Values by Crops

Year	Oats		Hay		Corn	
	Yield	Cash Value	Yield	Cash value	Yield	Cash value
	Bu.		Tons		Bu.	
1909....................	67.81	$23.73	4.10	$24.60	67.08	$32.87
1910....................	50.93	16.30	1.35	12.29	47.18	21.23
1911....................	46.25	18.50	2.90	34.51	56.94	30.18
1912....................	78.44	20.39	1.76	11.26	48.43	17.92
1913....................	91.88	29.40	2.92	19.27	58.20	30.85
1914....................	46.56	18.62	4.09	24.95	60.00	31.20
Average..............	63.65	$21.16	2.85	$21.15	56.31	$27.38

Average cash value per acre of all crops in the rotation..............................	$23.93
Average cost of production per acre of all crops in the rotation........................	11.23
Average annual net gain per acre..	$11.30

* Six tons of manure per acre.

The results for six years indicate that fall-plowed double-disked corn land for oats will not, ordinarily, give a sufficient increase in yield over that double disked only in spring to pay the additional cost of the plowing. However, on corn land that has not been kept comparatively free from weeds the previous year or on unduly compact soils, plowing for the succeeding grain crop is usually preferable to double disking only.

SPRING PLOWING FOR OATS

See Summary Table XXXV, page 54

Spring plowing followed by double disking for oats has been practiced each year on Plot 2, in each of the three series. Compared with the yields of oats in the three-year standard rotation, where double disking only of the corn field in preparation of the seedbed for the oat crop has been practiced, no consistent advantage either way is indicated. The lodging of the oats has averaged 14 per cent as compared with 24 per cent in the three-year standard rotation. The stands of clover and timothy on the spring-plowed ground have not been so thick or so even as on the double-disked corn ground in the three-year standard rotation, or as on the fall-plowed ground. Consequently the yields of hay are somewhat lower in the rotation where spring plowing for oats is practiced than in the three-year standard rotation, the six-year average yield being 2.61 tons and 2.89 tons per acre, respectively.

TABLE XXXIII

THREE-YEAR ROTATION—OATS, HAY, CORN*—SPRING PLOWING FOR OATS
Yields and Cash Values by Plots

Year	Plot 2—Series VII			Plot 2—Series VIII			Plot 2—Series IX		
	Crop	Yield	Cash value	Crop	Yield	Cash value	Crop	Yield	Cash value
1909...	Oats, bu.....	67.81	$23.73	Corn, bu.....	63.43	31.08	Hay, tons....	3.15	$18.90
1910...	Hay, tons....	1.00	9.10	Oats, bu.....	53.43	17.10	Corn, bu.....	46.07	20.73
1911...	Corn, bu.....	59.72	31.65	Hay, tons....	3.35	39.87	Oats, bu.....	43.13	17.25
1912...	Oats, bu.....	74.69	19.42	Corn, bu.....	46.37	17.16	Hay, tons....	1.75	11.20
1913...	Hay, tons....	2.78	18.35	Oats, bu.....	85.63	27.40	Corn, bu.....	61.72	32.71
1914...	Corn, bu.....	59.44	30.91	Hay, tons....	3.65	22.27	Oats, bu.....	47.50	19.00
Average...........		......	$22.19	....	......	$25.81	....	......	$19.97

Yields and Cash Values by Crops

Year	Oats		Hay		Corn	
	Yield	Cash value	Yield	Cash value	Yield	Cash value
	Bu.		Tons		Bu.	
1909....................	67.81	$23.73	3.15	$18.90	63.43	$31.08
1910....................	53.43	17.10	1.00	9.10	46.07	20.73
1911....................	43.13	17.25	3.35	39.87	59.72	31.65
1912....................	74.69	19.42	1.75	11.20	46.37	17.16
1913....................	85.63	27.40	2.78	18.35	61.72	32.71
1914....................	47.50	19.00	3.65	22.27	59.44	30.91
Average...............	62.03	$20.65	2.61	$19.95	56.13	$27.37

Average cash value per acre of all crops in the rotation..............................	$22.66
Average cost of production per acre of all crops in the rotation......................	11.93†
Average annual net gain per acre..	$10.73

* Six tons of manure per acre.

† This includes a charge of $1.50 per acre for plowing the corn ground for oats.

Comparing the yields of oats on the spring-plowed ground with those on the fall-plowed ground, in four years out of six they were practically equal, and in two years were in favor of fall plowing.

The yields of hay the year following the oats are in favor of spring plowing one year out of six. They are equal two years out of six, and in favor of fall plowing three years out of six.

Where both the spring- and fall-plowed land are double disked in spring in preparing the seedbed, as in this experiment, double disking only of the corn ground as practiced in the three-year standard rotation costs $1.50 per acre less than plowing in fall or in spring.

Spring plowing for grain is not considered good farm practice, as it delays the work of seeding, which should proceed with as little interruption as possible as soon as the ground is in good condition.

BROADCASTING VS. DRILLING GRASS AND LEGUME SEED WITH GRAIN

See Summary Table XXXV, page 54

Securing a stand of legumes, or legumes and grasses in a rotation is an important consideration. Upon its success each year depends the working out of the rotation without serious inconvenience as far as the desired annual acreage of each crop is concerned.

TABLE XXXIV

THREE-YEAR ROTATION—OATS, HAY, CORN*—GRASS SEED SOWN BROADCAST

Yields and Cash Values by Plots

Year	Plot 1—Series VII			Plot 1—Series VIII			Plot 1—Series IX		
	Crop	Yield	Cash value	Crop	Yield	Cash value	Crop	Yield	Cash value
1909...	Oats, bu.....	64.68	$22.64	Corn, bu.....	61.12	$29.95	Hay, tons....	3.20	$19.20
1910...	Hay, tons....	1.10	10.01	Oats, bu.....	44.37	14.19	Corn, bu.....	40.20	18.09
1911...	Corn, bu.....	45.13	23.92	Hay, tons....	2.95	35.11	Oats, bu.....	43.75	17.50
1912...	Oats, bu.....	70.63	18.36	Corn, bu.....	40.36	14.93	Hay, tons....	1.95	12.48
1913...	Hay, tons....	2.43	16.04	Oats, bu.....	73.44	23.50	Corn, bu.....	50.37	26.70
1914...	Corn, bu.....	60.69	31.56	Hay, tons....	4.29	26.17	Oats, bu.....	52.55	21.02
Average...........		......	$20.42	....	......	$23.98	....	......	$19.17

Yields and Cash Values by Crops

Year	Oats		Hay		Corn	
	Yield	Cash value	Yield	Cash value	Yield	Cash value
	Bu.		Tons		Bu.	
1909....................	64.68	$22.64	3.20	$19.20	61.12	$29.91
1910....................	44.37	14.19	1.10	10.01	40.20	18.09
1911....................	43.75	17.50	2.95	35.11	45.13	23.92
1912....................	70.63	18.36	1.95	12.48	40.36	14.93
1913....................	73.44	23.50	2.43	16.04	50.37	26.70
1914....................	52.55	21.02	4.29	26.17	60.69	31.56
Average..............	58.24	$19.54	2.65	$19.84	49.65	$24.19

Average cash value per acre of all crops in the rotation..............................	$21.19
Average cost of production per acre of all crops in the rotation.....................	11.67
Average annual net gain per acre...	$9.52

* Six tons of manure per acre.

On Plot 1, in each of the three series, the clover and timothy seed is sown broadcast as compared with drilling it in with the grain, the practice followed in the three-year standard rotation and in the other rotations on Field T where the grass and legume crops are included. The lower yields of corn in this rotation during part of the period are due to the removal of ears from the shocks by livestock while being driven along a road near the plots.

The six-year average yield of hay for the period has been 2.65 tons per acre as compared with 2.89 tons in the three-year standard rotation.

RESULTS AND CONCLUSIONS FOR THE TILLAGE AND MANURING INVESTIGATIONS

1. The rotation which did not receive applications of manure showed a consistent lowering of the yields of corn during the last four years of the experiment.
2. Applying the manure to meadow in the spring of the year preceding the corn did not appreciably increase the yields of hay and resulted in a small but fairly consistent lowering of the corn yields. The indications are that ordinarily manure should be applied preceding corn rather than to the meadow which precedes the corn crop.
3. For the six-year period, pasturing off the grass crop as compared with removing two hay crops each season in the rotation oats, hay, corn, gave no increase in yield of the oats or corn crops. On land not so well supplied with organic matter and nitrogen, a decided increase in yields of corn and grain may be expected from growing legumes and pasturing them off.
4. There was no appreciable difference in the yields of corn on fall- or early-spring-plowed clover sod. From several standpoints, fall plowing is the better farm practice in most cases.
5. The growing of oats was not so satisfactory on double-disked spring-plowed corn land as on double-disked fall-plowed land, or as on corn land double disked only. If corn land is weedy, low in productivity, or is unduly compact, plowing in preparation of the seedbed for grain is preferable to double disking only.
6. The stands of clover and timothy obtained when sown with oats on double-disked spring-plowed corn land were more uneven than on double-disked fall-plowed land, or on corn land double disked only, and the yields of hay for the six-year period were also less satisfactory.
7. For the six-year period, the yields of hay from broadcasting the timothy and clover seed averaged 2.65 tons per acre. In the three-year standard rotation, where the timothy and clover seed is drilled with the grain, the average yield per acre for the six-year period was 2.89 tons.

TABLE XXXV

SUMMARY OF AVERAGE YIELDS AND CASH VALUES—TILLAGE AND MANURING EXPERIMENTS, 1909-1914

THREE-YEAR ROTATION—OATS, HAY, CORN

Plot	Tillage methods	Yields and Cash Values by Crops						
			Oats		Hay		Corn	
		Manure per acre	Yield per acre	Cash value per acre	Yield per acre	Cash value per acre	Yield per acre	Cash value per acre
		Tons	Bu.		Tons		Bu.	
5	(Check) Double-disked corn land for oats. Fall plowing for oats.	6	61.56	$21.07	2.89	$21.37	57.92	$28.24
4	Double-disked corn land for oats. Fall plowing for corn, no manure	....	60.78	20.81	2.74	20.24	52.54	25.52
7	Double-disked corn land for oats. Fall plowing for corn, manure applied to meadow	6	65.73	22.06	2.88	21.07	54.64	26.58
8	Double-disked corn land for oats. Fall plowing for corn, grass pastured off	6	63.91	21.21	Pasture, mo. 51.71	10.26	55.34	26.98
6	Double-disked corn land for oats. Spring plowing for corn	6	63.79	21.57	2.98	22.31	57.18	27.92
3	Fall plowing for oats. Fall plowing for corn	6	63.65	21.16	2.85	21.15	56.31	27.38
2	Spring plowing for oats. Fall plowing for corn	6	62.03	20.65	2.61	19.95	56.13	27.37
1	Double-disked corn land for oats. Fall plowing for corn, grass seed sown broadcast	6	58.24	19.54	2.65	19.84	49.65	24.19

Plot	Tillage methods	All Crops in Each Rotation			
		Cash value per acre	Cost of production per acre	Net gain per acre	Increase + or decrease − compared with check
5	(Check) Double-disked corn land for oats. Fall plowing for oats.	$23.56	$11.67	$11.89	....
4	Double-disked corn land for oats. Fall plowing for corn, no manure	22.19	9.75	12.44	−$0.55
	Double-disked corn land for oats. Fall plowing for corn, manure applied to meadow	23.23	11.67	11.56	− 0.33
8	Double-disked corn land for oats. Fall plowing for corn, grass pastured off	19.48	10.21	9.27	− 2.52
6	Double-disked corn land for oats. Spring plowing for corn	23.93	11.67	12.26	− 0.31
3	Fall plowing for oats. Fall plowing for corn	23.23	11.93	11.30	− 0.59
2	Spring plowing for oats. Fall plowing for corn	22.66	11.93	10.73	− 1.16
1	Double-disked corn land for oats. Fall plowing for corn, grass seed sown broadcast	21.19	11.67	9.52	− 2.37

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The University of Minnesota

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COÖPERATIVE STORES IN MINNESOTA
1914

BY

E. DANA DURAND AND FRANK ROBOTKA

DIVISION OF RESEARCH IN AGRICULTURAL ECONOMICS

UNIVERSITY FARM, ST. PAUL

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SUMMARY

This summary relates only to the specific facts brought out by the statistical investigation of coöperative stores for 1913 and 1914.

The number of coöperative stores in Minnesota is about one hundred twenty-five and is changing very little.

The figures for 1914 as compared with 1913 show an increase in the average gross sales per store, which, however, may have been partly due to the prevailingly higher prices. The ratio of profit to sales increased appreciably.

About two thirds of the companies reporting regarding the distribution of profits pay dividends, but of these a considerable fraction pay on stock only. Comparison of the two years indicates a slight tendency toward increasing stock dividends at the expense of trade dividends.

For all stores adequately reporting, the average gross sales in 1914 were $45,836, the ratio of expense to gross sales was 11.7 per cent, and the ratio of net gain to gross sales, 4.5 per cent.

If the success of coöperative stores be measured by the ratio of net profit to gross sales—which is an approximately correct measure in view of the general policy of selling at competitive prices—the following conclusions as to the influence of various factors upon success may be drawn from an analysis of the statistics.

The factor showing the greatest influence is the ratio of total operating expense to gross sales. The lowest ratio is not always the best, but a fairly low ratio goes with much higher profits than a large ratio. The most satisfactory ratio appears to be about ten per cent.

The rapidity of turn-over of stock greatly influences success. The largest net profit was found where the gross sales were about three times the inventory, and the lowest where the gross sales were one and three quarters times the inventory.

Rarely does a coöperative store suffer because of too much paid-in capital stock. A capital equivalent to about thirty per cent of gross sales appears the most satisfactory. Stores with a relatively large indebtedness are generally decidedly less profitable than those with a small indebtedness.

The size of business has considerable influence upon success, altho some successful stores are found in groups of all sizes. Broadly speaking, the larger stores are the most successful and the very small stores make low profits.

In a business of a given size the most efficient management is secured by the managers with the higher salaries. They not only secure enough additional profit to pay higher salaries but show a higher net gain over and above all expenses.

COÖPERATIVE STORES IN MINNESOTA—1914

BY E. DANA DURAND AND FRANK ROBOTKA

GENERAL CONSIDERATIONS

The history of distributive coöperation in the United States is full of vicissitudes. There have been both successes and failures. Since the beginning of the movement in Massachusetts, in 1864, many attempts have been made to establish coöperative stores on the Rochdale plan which had been so successful in Great Britain. Among the organized attempts on a large scale may be mentioned that of the Patrons of Husbandry in 1867, the Sovereigns of Industry in 1874, the Knights of Labor in 1882, and the various efforts of the Farmers' Alliance. Altho in some cases brilliant successes were achieved, few of the stores fostered by these organized efforts remain.

Among other and more recent efforts, covering a less extensive territory, may be mentioned the Kansas State Coöperative Association, organized in 1901; the Washington State Coöperative Union, in 1903; and the Right Relationship League, in 1900. Of these, perhaps the last is meeting with the greatest success, its efforts being limited mainly to Wisconsin, Minnesota, and Iowa.

Efforts thus far to federate coöperative stores for the purpose of organizing a coöperative wholesale association have met with little permanent success.

A survey of the history of the coöperative store movement leads to the conclusion that by far the greater part of the unfavorable record is due to the unwise propaganda of enthusiasts and to inefficient management. Stores are frequently organized without due regard to existing conditions, on the crest of a wave of enthusiasm aroused by propagandists and promoters. That merchandising, as a general thing, does not lend itself to coöperative effort so advantageously as do production and marketing, is borne out by history and experience. In England and other European countries the success of distributive coöperation is due largely to the fact that the store is not a separate, isolated institution, but is a unit of a vast scheme of federated stores. The stores are financed coöperatively; they are insured coöperatively; they do their wholesale buying coöperatively; many of the goods sold are produced coöperatively. The entire course of the commodity from its production to its consumption is "paved with coöperation."

Under certain conditions the coöperative store can perform a legitimate economic function, but it will meet with success only when attendant circumstances are favorable. Often instead of a coöperative store a coöperative buying association, for the purpose of clubbing orders for limited classes of goods, should first be organized, and this. if business warrants, may eventually be transformed into a coöperative store, carrying a varied stock and catering to various classes of people.

Clarence Poe, in his "How Farmers Coöperate and Double Profits," lays down five rules which should be observed in organizing coöperative stores:

1. "They should never be started until a thoroly safe [and competent] manager is found.

2. "They should have what seems to be an adequate patronage in prospect—either through superseding an existing store or by taking over the patronage of a coöperative purchasing society.

3. "They should sell only for cash.

4. "They should comprise townsmen, as well as farmers.

5. "They should pay only legal interest on stock and divide all other profits on patronage."

To the above might be added that they should provide for the creation of a sinking fund, should be governed on the one-man-one-vote principle, and should apply at least a part of the profits as dividends on purchases of shares of stock, thus gradually increasing the working capital. This last principle has been one of the foremost factors in the marvelous success of the English coöperative stores.

If due regard be given the principles involved, and if proper management and guidance be provided, there is no question but that merchandising on a coöperative basis may attain a fair degree of success. Examples of successfully operated coöperative stores can readily be cited. That this movement will assume the proportions of some of the other phases of coöperation, however, is doubtful, for the primary reason that the benefits ordinarily to be derived are not so great and the incentive, therefore, is not so strong. Such permanent advance as will be made will be the result of slow growth. Here and there intolerable conditions have resulted in the spontaneous organization of coöperative stores. In many instances where stores have been organized to meet such conditions they have subsequently been discontinued because of lack of support owing to the removal of the conditions responsible for organization. In such a case the coöperative enterprise, having fulfilled its mission, cannot properly be called a failure.

In order to ascertain as nearly as possible the status and efficiency of the coöperative stores in Minnesota, and to determine the influence of certain internal factors on the degree of their success, an analysis covering the year 1914 was made, based on data contained in the annual reports which Minnesota coöperative stores are required to furnish the University. In some cases the data were inadequate but a sufficient number of stores have furnished satisfactory reports to afford an analysis of considerable value.

PRESENT STATUS OF COÖPERATIVE STORES IN MINNESOTA

NUMBER OF STORES

Because of the lack of adequate means of obtaining complete information each year regarding the organization and dissolution of coöperative stores, the number in actual operation at the present time cannot be definitely ascertained. The names appearing on the University's mailing list are obtained from various sources, none of which are entirely satisfactory. The available figures are as follows:

Number of stores making returns for 1914	62
Number making returns for 1913 but not for 1914	28
Number reported as existing but making no returns	36
Total	126

It is probable that most of the stores which reported for 1913 but failed to do so for 1914 were still in existence. The thirty-six listed as making no returns are known from other sources to have been in existence at least at some time during the two years. Undoubtedly some new associations were organized and others were discontinued during 1914, information concerning which is not available. The number of these is, perhaps, not large and the one may approximately counterbalance the other, hence the total of 126, as compared with 120 in 1913, is in all probability a close estimate.

GEOGRAPHIC DISTRIBUTION

Figure I shows the distribution of coöperative stores in Minnesota, by counties, January 1, 1915. It will be noted that the stores are as numerous in the less developed regions as in the southern part of the state, which means that they are relatively more important in the former. This is especially true of St. Louis county and the Red River Valley. The newly organized stores are largely confined to St. Louis county. This suggests that in the older parts of the state the needs of the farmers are more satisfactorily taken care of by privately-owned stores, and that the unfavorable circumstances which are usually responsible for the organization of coöperative stores exist in less degree than in the newer portions of the state. In the latter the private stores are often inadequate; not infrequently there is only one store in a village; and where there are more the competition among them is sometimes not keen. Again, in the southern half of the state, and to some extent in the east central portion and the Red River Valley, are located many farmers' elevators, coöperative creameries, and farmers' clubs, which in some cases purchase large quantities of supplies for their patrons.

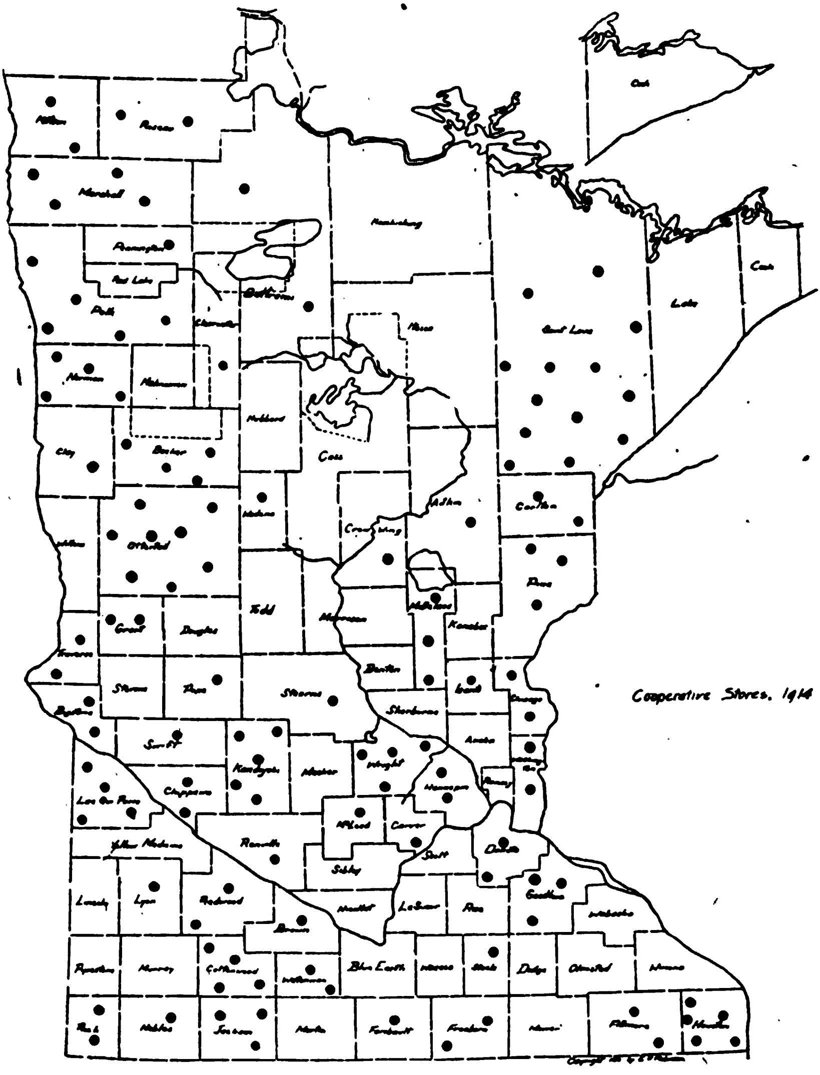

Fig. 1. Geographic Distribution of Coöperative Stores

VOLUME OF BUSINESS

In 1914 the aggregate sales of forty-two coöperative stores which reported this item comparatively amounted to $1,925,111, or an average of $45,836 per store, compared with an average of $42,518 for the same stores in 1913, a gain of approximately eight per cent. Assuming the same average for all of the 126 stores, the total sales would be approximately $5,800,000, but this is probably too liberal an estimate.

PROGRESS OF SELECTED STORES, 1913-1914

For the purpose of comparing certain other items of the business of the years 1913 and 1914, data furnished by twenty companies reporting for both years are presented in Table I.

TABLE I

COMPARISON OF SPECIFIED ITEMS FOR 20 COÖPERATIVE STORES REPORTING FOR 1913 AND 1914

Item	Average 1913	Average 1914	Percentage of increase
Gross sales	$32,025	$35,905	12.1
Gross profit	4,592	5,740	25.0
Total expense	3,461	4,216	21.8
Net profit	1,131	1,524	34.7
Indebtedness	8,738	8,816	0.9
	Percentage of gross sales		Difference in percentage
Gross profit	14.4	16.0	+1.6
Total expense	10.8	11.8	+1.0
Net profit	3.5	4.3	+0.8
Indebtedness	27.3	24.6	—2.7

An analysis of the foregoing figures, together with the data regarding dividends presented below, discloses a material improvement in the condition of the coöperative stores considered in this comparison. Altho the average expenses advanced 21.8 per cent between 1913 and 1914, the average net profits advanced 34.7 per cent, all on a basis of a 12.1 per cent increase in gross sales.

The ratio of expense to gross sales increased from 10.8 to 11.8 per cent. This increased cost of doing business, however, is more than counterbalanced by the increase in the ratio of gross profits to gross sales, which advanced from 14.4 to 16.0 per cent, so that the ratio of net profit rose from 3.5 to 4.3 per cent.

Of especial interest is the fact that the ratio of indebtedness to gross sales decreased from 27.3 to 24.6, a decrease of 2.7 per cent.

DIVIDENDS

Of the 42 companies reporting on the distribution of profits, 27, or 64 per cent, paid a dividend of some kind in 1914 as compared with 68 per cent in 1913. Of the 27 companies, 23 paid a dividend on stock, 16 paid a trade dividend to members, and 10 paid a trade dividend also to non-members. The figures follow:

Kind of Dividend Paid		Number
On stock only		11
On trade only		4
On stock and trade:		
Stock and membership trade	5	
Stock, membership and non-membership trade	7	
	—	12
Total		27

The fact that no dividend was paid by 15 of these 42 companies does not mean that the business was not operated at a profit. The average net profit of stores reporting no division of profits was $1,013 per store, and in only two instances was a net loss reported. Those reporting losses were stores recently organized; the others have been in operation from two to six years.

A comparison of the rate and kind of dividends declared in 1913 and in 1914 is of considerable interest, especially as it apparently discloses a tendency of the coöperative stores to depart from one of the most important essentials which characterize a coöperative enterprise; that is, there is an increasing tendency to distribute profits to stockholders rather than upon the basis of patronage. Data for 30 stores reporting for both years are given in Table II. The average rate of dividends on stock has increased from 6.2 to 7.2 per cent, whereas the average patronage dividend has fallen from 4.5 to 4.1 per cent.

TABLE II

Comparison of Rates and Kinds of Dividends Paid by 20 Coöperative Stores Reporting for 1913 and 1914

	Average rate	
	1913	1914
Dividend on stock	6.2	7.2
Membership trade dividend	5.6	5.3
Non-membership trade dividend	3.5	2.9
Average trade dividend	4.5	4.1

In the case of those stores which declared a dividend on stock only, the average rate in 1914 was 7.6 per cent.

Inasmuch as it is most advantageous to run a coöperative store on a profit basis, it is especially desirable in this class of coöperative enterprise that after allowing a moderate return on stock the balance of the profits be pro-rated on a patronage basis.

CLASSIFICATION OF EXPENSES

It would be desirable, if possible, to make a complete study of the expenses for a large number of stores, classifying them in detail, with a view to enabling managers of coöperative stores to ascertain how they stand with respect to the relative importance of different items of expense as compared with other stores. As has been shown, the cost of selling $100 worth of merchandise advanced from $10.80 in 1913 to $11.75 in 1914. The cost of doing business will probably continue to advance. Without question, the most powerful weapon with which the manager of a coöperative store may fight this increasing cost, as well as fight hard times, competition, and failure, is a thoro knowledge of the relative importance of the different items making up his own total expense. Such knowledge will enable him to see where economies may be effected. For instance, it may be found that it is cheaper to buy a horse and wagon than to hire delivering and drayage; or, on the other hand, it may be cheaper to hire this service. The relative cost in each case must determine which is the most economical course to pursue, and the relative cost can be determined only by a consistent tho simple classification of the expenses. An analysis of his own expenses will obviously be much more useful to the manager of a store if he has comparative data for other stores.

In view, however, of the fact that one fourth of the total expenses reported by the stores to the University were grouped as "unclassified" or "miscellaneous," it can readily be seen that entirely reliable figures regarding the distribution of expenses cannot be submitted. However, the figures as reported are presented in Table III. The classification appearing in the table consists of items as they were reported to this Division and is not intended to serve as a model. Suggestions for a satisfactory classification are presented on page 30.

The fact that the total expense as computed from details equals 11.71 per cent of sales as compared with 11.75 per cent based on the total reported expense, indicates that the aggregate of the several items approximates very closely the actual cost.

TABLE III

DISTRIBUTION OF EXPENSES OF COÖPERATIVE STORES

Item	Percentage of gross sales		Percentage of total expense	
Overhead expense:				
Salary (manager)	2.04		17.42	
Taxes	0.32		2.72	
Insurance	0.28		2.40	
Rent	0.27		2.30	
Depreciation	0.25		2.14	
Fuel and light	0.05		0.43	
Overhead, unclassified	0.72		6.15	
Total overhead expense		3.93		33.56

TABLE III—*Continued*

Distribution of Expenses of Coöperative Stores

Item	Percentage of gross sales		Percentage of total expense	
Trade expense:				
Freight, drayage, and delivery	0.82		7.00	
Labor	3.96		33.81	
Interest	0.74		6.33	
Advertising	0.09		0.77	
Bad debts	0.07		0.60	
Trade unclassified	0.21		1.79	
Total trade expense		5.89		50.30
General unclassified		1.89		16.14
Total expense		11.71		100.00

For convenience of comparison the items of expense are presented in Table IV in the order of their importance.

It is necessary to bear in mind that all of the specific items in these tables would be increased more or less were all the unclassified expenses properly distributed. The items that would likely be affected most are rent, depreciation, fuel and light, advertising, and bad debts, as these items are less often reported separately. Of course, a considerable proportion of the unclassified expense consists of miscellaneous items not falling under any of the more specific items listed.

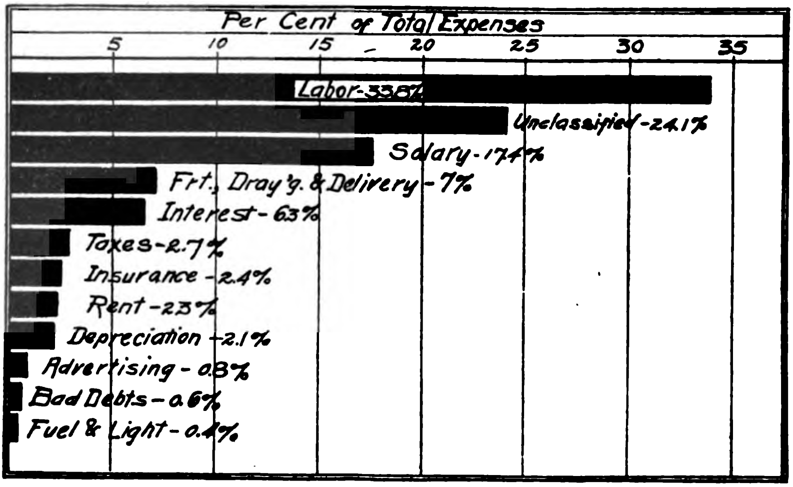

Fig. 2. Relative Importance of Various Expense Items

It will be noted at first glance that labor and salaries are responsible for a little over half of the total expense. These items, combined with unclassified items, or miscellaneous expense, freight, drayage and delivery, constitute over four fifths of all expenses; hence it is logical to expect that in a close scrutiny of the expenditures for these items lies the greatest possibility of a material cutting down of the expenses.

TABLE IV

Expenses Itemized in Order of Importance

Item	Percentage of total expense
Labor	33.81
Unclassified	24.08
Salary	17.42
Freight, drayage, and delivery	7.00
Interest	6.33
Taxes	2.72
Insurance	2.40
Rent	2.30
Depreciation	2.14
Advertising	0.77
Bad debts	0.60
Fuel and light	0.43
Total	100.00

INFLUENCE OF VARIOUS FACTORS ON NET GAIN

The question naturally arises, what is a reasonable ratio between the gross sales, indebtedness, stock carried, capital, total expense, and the different items of expense? Is there a definite relation existing between each or any of the items and the net profit, and if so, which items exert the greatest influence upon the net profits? Lack of sufficient data renders a satisfactory answer difficult. A comparison of certain of the ratios, however, is made in Tables V to XII, inclusive.

It will be noted that the only available measure of the degree of success of the different stores is the ratio of net profit to gross sales. This in some cases may not be a true indication of success, as the policy of some successful stores may be toward lower prices rather than toward larger profits. However, the coöperative store should be run on the plan of charging regular competitive prices, and it ordinarily is, therefore a comparison on the above basis undoubtedly is more satisfactory than any other.

RATE OF PROFIT ON SALES

The first step in such an analysis of the factors in store operation may be made by classifying stores according to their rates of profit on sales. This is done in Table V.

As might perhaps be supposed, as the rate of profit on gross sales increases, the average gross sales themselves increase and all other factors decrease. Of course, there is no means of telling how much each factor affects the profit. Moreover, there is an association among the factors themselves. Thus large sales are likely to mean rapid sales, making possible lower ratios of inventory, capital stock, and debt to sales, and also tending to lower the expense ratio.

TABLE V

CLASSIFICATION OF STORES ACCORDING TO RATIO OF NET PROFIT TO GROSS SALES

Class according to ratio of net profit to gross sales	Average net gain percentage of gross sales	Average gross sales	Ratio of item specified to gross sales					
			Capital stock	Inventory	Debt	Labor expense	Unclassified expense	Total expense
			Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Less than 2 per cent.........	1.2	$27,710	33.7	42.0	29.0	5.7	3.3	17.5
2 – 4 per cent..	3.8	40,119	27.3	35.3	23.0	4.7	1.6	11.7
4 – 6 per cent..	5.5	46,875	24.2	31.3	18.8	4.4	2.9	11.6
More than 6 per cent....	7.6	48,409	20.6	28.6	13.5	4.1	*	10.5

* Insufficient data.

Experience in business, however, generally suggests that it is not always advisable to attempt to keep the inventory (or stock) debt, capital, and total expense at the lowest possible point, but rather that the point of greatest efficiency for some of these factors tends to avoid extremes. Further analysis of the statistics confirms this view.

SIZE OF BUSINESS

The influence of the size of business upon net profit is brought out in a different way by classifying stores according to their gross sales.

TABLE VI

CLASSIFICATION OF STORES ACCORDING TO AMOUNT OF ANNUAL GROSS SALES

Class according to amount of gross sales	Average gross sales	Ratio of item specified to gross sales						
		Capital stock	Inventory	Debt	Labor expense	Unclassified expense	Total expense	Net gain
		Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Less than $20,000...	$11,630	24.6	40.5	34.1	4.9	2.2	13.4	3.4
$20,000–$40,000....	30,510	24.6	36.0	25.0	4.8	2.9	12.6	4.4
$40,000–$60,000....	48,676	23.9	33.4	22.5	4.9	3.2	12.1	5.2
More than $60,000..	71,787	19.2	27.0	14.5	4.4	3.5	11.4	5.4

From Table VI it is again seen that, as a general rule, there is a tendency for the rate of net profit to increase as gross sales increase, the increase in rate of net gain, however, being, naturally enough, by no means proportional. It will be noted that as gross sales increase, the ratios of inventory, debt, capital, and total expense to sales decrease, doubtless largely for the reason already suggested. This decline in the ratio of labor expense to increase of sales is so slight as to be negligible. Unclassified expenses reported are relatively larger in large enterprises than in small ones, but this may be due in whole or in part to differences among the individual stores in the method of classifying expenses. It cannot be said that the increase in rate of net gain is due entirely to increased size of business; it may be due, in part, to the influence of one or all of the other factors reacting upon each other. Neither can it be concluded that, as inventory, debt, capital, and total expense are lower where gross sales and net gain are higher, the higher rate of net gain resulted because of the keeping down of these factors; it may have resulted in spite of this association of the different factors. The question then arises, what is the measure of the influence of each of these factors?

EXPENSE

For instance, in any business it is good policy to keep the expense of operating reasonable, yet it is possible so to restrict the expenditures as to interfere with the most efficient management. This fact is illustrated by a classification of the stores on the basis of the ratio of expense to sales, as shown in Table VII.

TABLE VII

CLASSIFICATION OF STORES ACCORDING TO RATIO OF EXPENSE TO GROSS SALES

Class according to ratio of expense to gross sales	Average expense, percentage of gross sales	Average gross sales	Ratio of item specified to gross sales					
			Capital stock	Inventory	Debt	Labor expense	Unclassified expense	Net profit
			Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Less than 8 per cent.........	7.7	$27,610	17.6	32.9	17.1	2.1	1.4	2.9
8–11 per cent..	9.9	50,581	26.5	29.0	13.4	3.7	2.3	6.1
11–14 per cent..	12.1	47,068	21.8	34.8	23.3	5.0	*	4.8
14–17 per cent..	14.8	35,685	27.4	36.3	27.7	6.6	2.5	3.4
More than 17 per cent.....	18.7	25,900	51.3	50.5	*	7.0	*	0.7

* Insufficient data.

Here it is seen that on the average the highest rate of net gain is not associated with the lowest expense ratio but with an expense of from 8 to 11 per cent. It is to be noted that at this point gross sales are highest and the ratio of inventory to gross sales lowest, and that capital slightly exceeds one fourth of gross sales. As in Tables V and VI, the columns in this table other than net gain are given, not to show necessarily a causal relation, but rather to show in what proportions these other factors are associated with the one under consideration in producing given results.

INVENTORY

Let us now consider the influence of the inventory, or stock carried, upon the rate of net gain. A classification of the stores based on the relation of the amount of stock carried to the gross sales is presented in Table VIII. The ratio of inventory to sales, in a rough way, measures the rapidity of turn-over. Of course, the significance of the figures is lessened by the fact that the inventory represents for each store only a single date, at which the inventory may have chanced to be materially above or below normal. However, where a considerable number of stores are grouped, such deviations tend to counterbalance one another.

TABLE VIII

CLASSIFICATION OF STORES ACCORDING TO RATIO OF INVENTORY TO GROSS SALES

Class according to ratio of inventory to gross sales	Average inventory, percentage of gross sales	Average gross sales	Ratio of items specified to gross sales					
			Capital stock	Debt	Labor expense	Unclassified expense	Total expense	Net profit
			Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Less than 15 per cent.....	12.4	$55,900	9.4	15.6	4.9	2.3	12.2	3.1
15–25 per cent..	19.7	54,271	28.0	15.3	4.1	*	9.9	5.3
25–35 per cent..	31.0	43,825	22.3	13.3	3.9	2.7	10.8	6.0
35–45 per cent..	39.7	38,151	29.8	19.7	6.1	2.0	13.7	4.0
More than 45 per cent.....	57.1	30,800	27.5	35.6	5.4	2.7	14.0	1.3

* Insufficient data.

As might be expected, the ratio of stock carried to sales, which measures the rate of turn-over, has a marked influence on net profits. Here it is found, however, that neither the largest nor the smallest stock ratio yields the largest rate of net profit, but rather a stock of from 25 to 35 per cent of gross sales. It is in the group having also a stock equal to from 15 to 25 per cent of gross sales that the expense of operation shows the lowest ratio to gross sales. This group also ranks next to the highest in rate of profit. Inasmuch as keeping the stock down to the lowest possible point (without losing sales) or what amounts to the same thing, turning the stock as frequently as possible, is a task calling for a high degree of managerial ability, this classification strongly emphasizes the importance of efficient management.

A large debt is naturally associated with a large stock and slow turn-over, and is not only a source of expense, but also a continual source of embarrassment to the manager and the business. This latter unfavorable situation becomes more significant when it is noted that it is most commonly associated with the small enterprise.

LABOR

More than one third of all expenses (see Table IV) consists of labor, hence it is of great interest to note the influence of this factor on net profit. The result of a classification on the basis of the ratio of labor expense to gross sales is given in Table IX.

TABLE IX

Classification of Stores According to Ratio of Labor Expense to Gross Sales

Class according to ratio of labor expense to gross sales	Average labor expense, percentage of gross sales	Gross sales	Ratio of item specified to gross sales					
			Capital stock	Inventory	Debt	Unclassified expense	Total expense	Net profit
			Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Less than 4 per cent..........	3.1	$42,974	24.2	32.0	14.2	1.6	9.2	4.8
4 – 5 per cent..	4.4	47,509	19.3	33.4	18.4	1.8	10.9	5.6
5 – 6 per cent..	5.5	50,659	25.9	33.5	27.6	*	13.9	3.8
More than 6 per cent.....	7.2	37,213	20.6	36.0	*	3.2	13.1	2.8

* Insufficient data.

The cost of labor influences both total expense and net gain in approximately the same degree, the net gain in general decreasing and total expenses increasing with increase in labor expense. However, the highest rate of profit is not associated with the lowest ratio of labor expense, but with the next to the lowest. The fact that the smallest average gross sales are associated in this instance with the largest labor cost leads to the conclusion that there is a less economical utilization of labor in the small business and that when this item exceeds 6 per cent of gross sales there is occasion to believe that the labor is not efficiently utilized.

TABLE X

Classification of Stores According to Amount of Capital Stock

Class according to ratio of capital stock to gross sales	Average capital stock, percentage of gross sales	Average gross sales	Ratio of item specified to gross sales					
			Inventory	Indebtedness	Labor expense	Unclassified expense	Total expense	Net profit
			Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Less than 15 per cent.....	11.0	$52,000	27.3	18.1	5.0	1.8	11.7	4.1
15–20 per cent..	17.6	40,903	30.8	19.9	5.0	3.6	10.6	4.6
20–25 per cent..	24.2	43,115	32.8	18.8	4.5	*	11.2	5.9
More than 25 per cent.....	28.2	43,005	44.4	28.1	3.8	*	10.9	5.9

* Insufficient data.

CAPITAL STOCK

The amount of capital used in a corporate business is, of course, represented by the paid-in capital stock plus borrowed money. The classification on the basis of the ratio of capital stock to annual gross sales, Table X, reveals a tendency for the net profits to increase as this ratio increases. This relation, however, is not maintained in the last class, inasmuch as the net profits are no larger than for the class preceding. This may be due, however, to the slow turn-over and the large indebtedness occurring in the latter class. A tendency for the stock carried to increase as the ratio of capital stock to annual gross sales increases is also apparent. Only when this ratio exceeds 25 per cent, however, is the ratio excessive.

Adequate capital is of vital importance in any kind of business. It is essential that the manager take advantage of merchandise discounts by paying bills within the discount period; he must be able to buy when markets are favorable, and in quantities offering most advantageous terms. He must have ample help and equipment, and varied, though not extensive, stock; above all, he must maintain the credit reputation of the firm, hence he cannot always depend upon borrowing money in order to obtain the necessary working capital.

INDEBTEDNESS

As already stated, the presence of indebtedness in the case of a coöperative store may mean merely that the store has deliberately adopted the policy of obtaining part of the needed capital by borrowing money, or it may mean that the store is in a rather unsatisfactory financial condition—that it is not making very satisfactory profit or that it has been unable to raise sufficient funds from capital stock to provide a satisfactory stock of goods and equipment. The second, however, is so often the explanation that we should expect to find stores with a large ratio of indebtedness to gross sales less profitable than those with a small ratio. This is shown to be the case by Table XI.

TABLE XI

CLASSIFICATION OF STORES ACCORDING TO RATIO OF INDEBTEDNESS TO GROSS SALES

Class according to ratio of indebtedness to gross sales	Average indebtedness, percentage of gross sales	Average gross sales	Ratio of item specified to gross sales					
			Capital stock	Inventory	Labor expense	Unclassified expense	Total expense	Net profit
			Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Less than 10 per cent	4.7	$37,264	22.1	27.0	4.4	1.8	11.1	5.2
10–20 per cent	13.9	62,128	22.6	22.8	3.8	1.4	10.2	5.9
20–30 per cent	26.4	37,394	18.7	38.1	4.3	2.2	10.8	4.6
More than 30 per cent	39.9	35,041	31.6	53.6	4.6	2.0	13.6	3.3

Excepting the first group, there is a regular diminution of the rate of net gain with an increasing ratio of indebtedness. When indebtedness exceeds 20 per cent of gross sales, the rate of net gain drops decidedly. Excluding the case where the indebtedness is less than 10 per cent of gross sales, the ratios of inventory, total expense, and labor expense to gross sales increase as the debt increases, creating an undesirable association of these factors, which in all probability has a more pronounced influence on net gain than is indicated in this classification. Table V shows a regular decrease in debt ratio as the rate of net gain increases. Altho the data regarding this point are inadequate to serve as a basis for an unqualified conclusion, the classification on basis of expense indicates a regular increase of indebtedness as expenses increase. Table VI, in which stores are classified according to size of business, likewise reveals the existence of a strong inverse relation between indebtedness and net gain. Tables VIII and X also support the same conclusion.

UNCLASSIFIED EXPENSE

Of considerable interest is the study of the relation existing between the unclassified expenses, "miscellaneous" as they are usually termed, and the degree of success of the business. There is a legitimate place in the accounting system for a "miscellaneous expense" account, but, like the "general expense" account, it very often serves as a general dumping-ground for a large variety of items which properly belong to other accounts, thus defeating in a measure one of the main purposes of keeping accounts, namely, to supply information necessary to secure a more intelligent management of the business. A large miscellaneous expense ratio is, therefore, likely to accompany low profits, both because it includes costs which are themselves needlessly high and because it shows poor methods of keeping the books and records, and this points to inefficiency of the general management of the enterprise.

The influence of unclassified expense is not a direct influence. It is rather a result of other influences, and is usually associated in the greatest degree with other unfavorable circumstances to which must be attributed the direct influence on the net gain. In fact, the magnitude of the unclassified expenses very often is a good index of the degree of managerial efficiency exhibited in matters other than the keeping of the books. The advantage derived from an adequate classification of expenses is that the magnitude of expenditures for different purposes is definitely known, which knowledge, in a well-managed business, will result in changes in policy with a view to decreasing expenses, or eliminating those commodities or ventures resulting in losses.

The classification of the stores on the basis of unclassified expense, Table XII, reveals a close relationship between the magnitude of the unclassified expenses and the net gain.

It will be noted that the net gain decreases and the total expense increases rapidly as the ratio of unclassified expenses to gross sales increases, but that there is no such relation existing between this item and the size of business as indicated by average gross sales. The tendency to abuse the "miscellaneous expense" account appears to be as great in the large as in the small business. A fact not shown in Table

XII is that there is a decided decrease in the salary of the manager as the ratio of unclassified expenses increases. This tends to support the statement previously made, that this account is a fair index of the efficiency of the manager, assuming, of course, that the salary he receives is a fairly reliable measure of his competency.

TABLE XII

Classification of Stores According to Ratio of Unclassified Expense to Gross Sales

Class according to ratio of unclassified expense and gross sales	Average unclassified expense, percentage of gross sales	Average gross sales	Ratio of item specified to gross sales					
			Capital stock	Inventory	Indebtedness	Labor expense	Total expense	Net profit
			Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Less than 1 per cent	0.5	$47,327	*	32.1	*	4.5	10.3	6.2
1 - 2 per cent	1.4	46,430	18.3	31.7	21.5	5.4	11.4	5.6
2 - 3 per cent	2.4	45,280	16.5	32.8	14.4	4.6	11.9	3.7
More than 3 per cent	6.0	48,557	27.0	29.0	*	7.0	14.5	2.9

* Insufficient data.

SALARY OF MANAGER

In order to bring out the difference in the results produced by managers receiving high and low salaries, it is necessary to make comparisons among stores of approximately similar size. Consequently the stores were classified by size into four groups according to the amount of annual sales. After determining the average salary of managers for each group, the stores in each group were separated into two divisions according as the managers received more or less than the average salary for the group. The amount of gross sales, and the ratios of capital, expense, salary, and net gain to gross sales, for stores where managers received less than the average salary for the group (called Class 1) were then compared with similar items for stores where the managers received more than the average salary for the group (Class 2). The results are presented herewith in Tables XIII and XIV. The figures given in Table XIV (based on the data in Table XIII) represent the percentage deviations of the averages of the specified items for each class from the average of the entire group.

A careful study of Table XIV and Figure 3 reveals the fact that in a business of a given size, the most efficient management is secured by the manager receiving the larger salary. For instance, considering the first group consisting of stores doing an annual business of less than $25,000, we find for managers in Class 1 that, while the gross sales were only 13 per cent less than the average for the group, the net profit was 40 per cent less, despite the fact that the expense was 2.4 per cent more than the average and the capital 14 per cent more. The salary in this case was 35.3 per cent less than the average for this group of stores. In considering managers in Class 2, we find they obtained a net gain of 53 per cent above the average, with gross sales of only 13.3 per cent above the average. Their expense and capital were less than the average. This favorable showing was associated with a salary 28 per cent above the average for this group.

TABLE XIII

Specified Items for Stores Where Managers Received Less Than Average Salary for Each Group of Stores (Class 1) Compared With Same Items Where Salary Was More Than Average (Class 2)

Class according to amount of gross sales	Average gross sales		Ratio of specified item to gross sales							
			Net gain		Expense		Salary of Mgr.		Capital stock	
	Class 1	Class 2	Class 1	Class 2	Class 1	Class 2	Class 1	Class 2	Class 1	Class 2
			Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Less than $25,000	$14,187	$16,339	1.0	2.6	12.9	12.6	2.78	5.5	27.8	22.1
$25,000 - $40,000	35,461	35,000	3.9	5.1	9.3	10.8	2.70	3.7	24.6	22.4
$40,000 - $60,000	44,788	48,948	4.0	5.2	12.5	12.0	1.96	2.51	20.4	29.4
More than $60,000	65,098	70,131	3.2	7.0	9.8	11.3	1.53	1.66	17.6	14.5
Average*	39,884	42,605	3.0	5.0	11.1	11.7	2.24	3.34	22.6	22.2

* Simple average obtained by adding groups and dividing by 4.

TABLE XIV

Percentages of Deviation of Specified Items From the Average for Stores Where Managers Received Less Than Average Salary for Each Group of Stores (Class 1) Compared With Same Items Where Salary Was More Than Average (Class 2)

Annual gross sales	Deviation from average for group									
	Gross sales		Net gain		Expense		Salary		Capital stock	
	Class 1	Class 2	Class 1	Class 2	Class 1	Class 2	Class 1	Class 2	Class 1	Class 2
	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Less than $25,000	−13.0*	+13.3†	−40.0	+53.0	+2.4	−0.8	−35.3	+28.0	+14.0	−5.0
$25,000 - $40,000	+1.3	−1.3	−13.6	+13.6	−13.9	+14.7	−15.6	+15.6	+4.7	−4.7
$40,000 - $60,000	−8.5	+5.7	−16.1	+10.0	+2.5	−1.6	−15.5	+8.2	−18.0	+18.0
More than $60,000	−7.2	+5.5	−41.0	+29.6	−6.5	+7.6	−5.0	+3.1	+38.6	−17.6
Average‡	−6.8	+5.8	−27.7	+26.6	−3.9	+5.0	−17.8	+13.7	+9.8	−2.3

* A minus sign indicates less than average.
† A plus sign indicates more than average.
‡ Simple average.

The influence of salary is somewhat doubtful in the second group of stores, inasmuch as the higher gain of stores paying the higher salaries was secured at a considerable increase in expense. It will be noted that the deviations from the average of gross sales and capital are slight.

In the next group of stores, those whose annual gross sales range from $40,000 to $60,000, we find for managers in Class 1, a gain 16.1

per cent below the average associated with gross sales 8.5 per cent below the average, and expense 2.5 per cent above the average. In this case the more highly paid managers clearly conducted the business more efficiently.

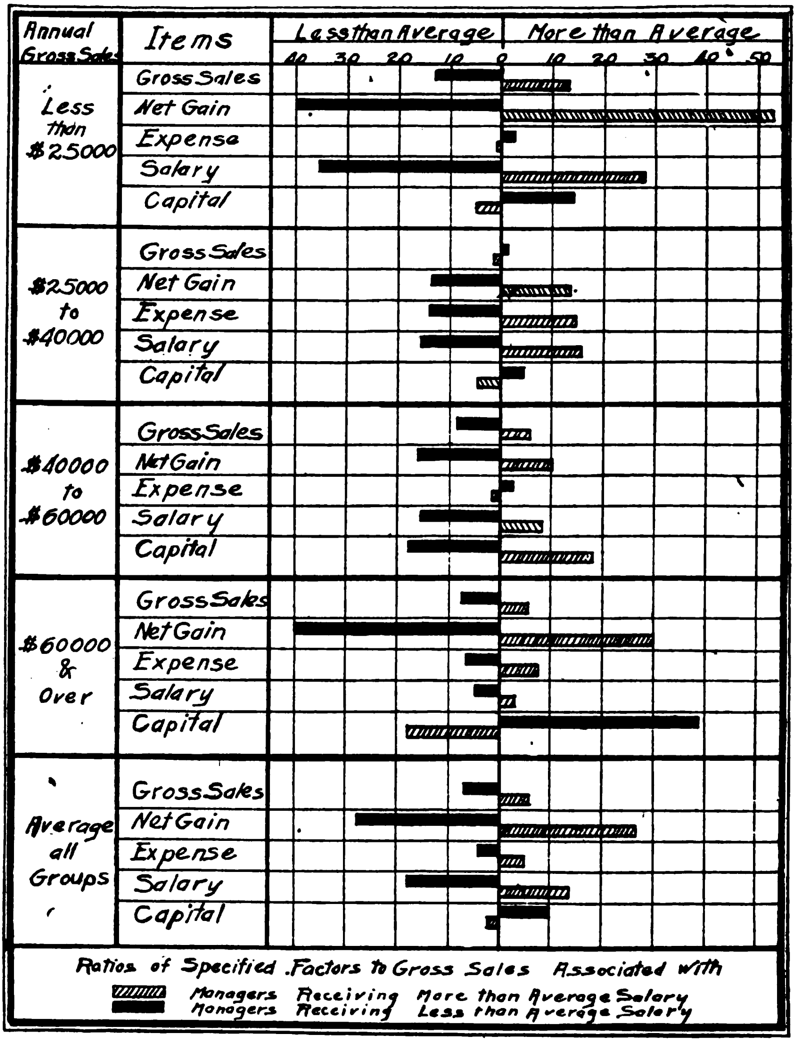

Fig. 3. Relation of Salary of Manager to Net Gain

Deviation of specified items from average is expressed in percentages.

In the last group of stores, we find for managers in Class 1 a net gain of 41.0 per cent below the average associated with gross sales 7.2 per cent below the average. A great variation in net gain is associated with a relatively small variation in salary. As in the second group, however, the average expense for Class 1 is lower than for Class 2. In this group a very inefficient utilization of capital by managers receiving the lower salaries is shown.

What then is the sum of the variations in the different groups, and what conclusion can be reached? The variations of net gain from the average as between Class 1 and Class 2 are the greatest in the largest and in the smallest enterprise, which may be interpreted as meaning that in these enterprises are to be found the greatest risks and the greatest need of more efficient management. In the enterprises of moderate size, the variations are not so marked, altho such variations as occur follow consistently the variations in salary.

The averages of the variations for the several groups indicate clearly the relation between salary and efficiency of management. With an excess in salary of 13.7 per cent above the average, the better paid managers produced a gain 26.6 per cent in excess of the average. This result was secured with but slightly greater gross sales and expense and with a capital smaller than the average.

FAVORABLE AND UNFAVORABLE ASSOCIATION OF THE VARIOUS FACTORS

THE MOST FAVORABLE ASSOCIATION

We are now ready to deduce some conclusions regarding the most advantageous association of the different factors in order to secure the largest net profit. In each of the preceding tables was given a classification of the stores on a different basis. Each classification indicated varying amounts of ratios of the particular factor considered associated with various net returns. Suppose we now select from each of the foregoing classifications that association of the different factors which resulted in the highest net returns, and compare the result with those associations which resulted in the lowest net returns, and also with the average of all stores. For instance, in Table VI we found the highest net gain was secured in the last group, namely, the one in which the annual gross sales were $60,000 or more. Associated with this size of business we find certain ratios representing the other factors. In like manner the most profitable association of factors in the other tables was selected. The result is presented in Table XV. Table XVI consists of similar data from the several classifications, but in this case the least profitable instead of the most profitable associations of the different factors were selected.

Confining ourselves for the moment to Table XV, several things are to be noted. First, reading the figures in black-faced type diagonally from left to right, we have a combination of ratios which represent an association of the different factors tending to approach the ideal. Inasmuch as these and more favorable figures have actually been attained, they are not ideal. In each case the figure given is an average, hence some stores have attained more favorable results than these averages. Each figure in black-faced type represents the ratio of the particular factor in each classification which yielded the highest net gain. However, these figures were not found in actual association *with each other*. For instance, under annual gross sales, reading from left to right, we find the group of stores which yielded the highest net gain averaged annual gross sales amounting to $71,787. This average volume of business was actually associated with ratios of the other factors as designated in the table, reading directly from left to right. The resulting net gain was 5.4 per cent. Let us now suppose that this average volume of business was associated with ratios for the other factors corresponding to the figures in black-faced type. Then, theoretically, the net gain ought to be higher, in fact it ought to be higher than 7.6 per cent, the average for the group showing the highest average when the stores are classed according to net profit.

TABLE XV

AMOUNT OF GROSS SALES AND RATIOS OF SPECIFIED FACTORS TO GROSS SALES ASSOCIATED WITH LARGEST NET RETURN IN THE SEVERAL CLASSIFICATIONS

Basis of classification	Annual gross sales	Ratio of specified item to gross sales						
		Capital	Indebtedness	Inventory	Labor expense	Unclassified expense	Total expense	Net profit
		Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Annual gross sales	**$71,787**	19.2	14.5	27.0	4.4	2.6	11.4	5.4
Capital	43,115	**24.2**	18.8	32.8	4.5	*	11.2	5.9
Indebtedness	62,128	22.6	**13.9**	22.8	3.8	1.4	10.2	5.9
Inventory	43,825	22.3	13.3	**31.0**	3.9	2.7	10.8	6.0
Labor expense	47,509	19.3	18.4	33.4	**4.4**	1.8	10.9	5.6
Unclassified expense	47,327	*	*	32.1	4.5	**0.5**	10.3	6.2
Total expense	50,581	26.5	13.4	29.0	3.7	2.1	**9.9**	6.1
Net profit	$48,409	20.6	13.5	28.6	4.4	*	10.5	7.6

* Insufficient data.

It is interesting to compare the factors shown in the black type with those in the bottom line of the table representing the stores that, when stores are classified according to the ratio of their net profits to gross sales, showed the highest ratio. It will be observed that the figure for average gross sales is much larger and the ratio of capital to sales much larger, the ratio of expense to sales somewhat smaller, and the other comparable factors not greatly different.

The figures under each heading secured by the different classifications, tend, within reasonable limits, to approximate each other, that is, in the well-managed enterprises the different factors tend fairly consistently toward a practical best relationship. The fact, however, that each figure is the result of a classification on a different basis, precludes the possibility of their serving as absolute checks against each other.

It is of interest to note the relation existing between the figures in this table and the average of the same items, for all stores as shown in Table XVII. The figures under each heading exhibit a tendency to approximate the average for all stores, but in a majority of cases are more favorable. This might be interpreted as meaning that there is little or no difference between these most profitable associations of the factors and that association resulting by taking the average of these factors for all stores. Were this true in this case, we would expect it to be true in analyzing Table XVI as well. In Table XVI, however, we find no such tendency of the figures for each factor to approximate the average, but we find them to be decidedly less favorable.

THE LEAST FAVORABLE ASSOCIATION

Turning now to Table XVI, consisting of the least profitable combination of the different factors in each of the classifications presented in Tables V to XII, we find some extremely pronounced differences from similar items in Table XV.

TABLE XVI

Amount of Gross Sales and Ratios of Specified Factors to Gross Sales Associated with Smallest Net Return in the Several Classifications

Basis of classification	Annual gross sales	Ratio of specified item to gross sales						
		Capital	Indebtedness	Inventory	Labor expense	Unclassified expense	Total expense	Net profit
		Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Annual gross sales	**$11,680**	24.6	34.1	40.5	4.9	2.6	13.4	3.4
Capital	52,000	**11.0**	18.1	27.3	5.0	1.8	11.7	4.1
Indebtedness	35,041	31.6	**39.9**	53.6	4.6	2.0	13.6	3.3
Inventory	30,800	27.5	35.6	**57.1**	5.4	2.7	14.0	1.3
Labor expense	37,213	20.6	*	36.0	**7.2**	3.2	16.1	2.8
Unclassified expense	48,557	27.0	*	29.0	7.0	**4.9**	14.5	2.9
Total expense	25,900	51.3	25.5	50.5	7.0	*	**18.7**	0.7
Net profit	$27,710	33.7	29.0	42.0	6.1	3.3	17.5	1.2

* Insufficient data.

Not only do we find pronounced difference when comparing these two tables, but the deviations of the ratios of the several factors from the average of all stores is especially marked. In Table XV, by reading the ratios in black-faced type, for the several factors, we secure an association which is most favorable. Similarly in Table XVI we secure the opposite extreme. It is probable with such an extremely unfavorable combination of factors, the net profit would be less than zero. As in Table XV, the ratios in black-faced type, representing the least favorable proportion of each factor, were not actually all associated together. It will again be noted that there is a certain resemblance between the figures under the several combinations. Moreover, in every column except that relating to capital, nearly every figure in Table XVI is more unfavorable than any figure in Table XV.

COMPARISON WITH AVERAGES FOR ALL STORES

For the purpose of facilitating comparison, the figures in black-faced type from Tables XV and XVI are brought together in Table XVII and compared with the averages of similar items for all stores. This table shows in a pronounced manner some of the conditions more or less under the control of the manager and board of directors, which determine the success or failure of the enterprise. In a successful business will be found large gross sales, a fairly low expense ratio, frequent turn-over, relatively small labor expense, small debt, and an efficient system of accounting resulting in a small item for "unclassified expense."

TABLE XVII

THE MOST FAVORABLE RATIO OF EACH FACTOR COMPARED WITH THE LEAST FAVORABLE RATIO AND WITH THE AVERAGE FOR ALL STORES*

Factor	Most favorable ratio	Average all stores	Least favorable ratio	Percentage above or below	
				Most favorable	Least favorable
Size of business	$71,789	$45,836	$11,630	+56.0†	−74.5‡
	Per cent	Per cent	Per cent		
Net gain	7.6	4.5	1.2	+70.0	−73.3
Expense	9.9	11.7	18.7	−15.4	+59.5
Inventory	31.0	30.0	57.1	+ 3.3	+90.5
Labor	4.1	4.0	7.2	+10.0	+82.0
Capital	24.2	20.4	11.0	+18.6	−46.1
Debt	13.9	17.5	39.9	−21.0	+128.0
Unclassified expense	0.5	2.8	4.9	−82.0	+73.8

* Excepting first item, figures represent ratios of specific items to gross sales.

† A plus sign indicates above average.

‡ A minus sign indicates below average.

In an unprofitable business will be found a converse association of these factors. Especially pronounced in the least profitable enterprises is the extent to which the ratio of indebtedness to sales exceeds the average for all stores. The ratio of inventory, or stock carried, to sales is far above the average. Labor expenses, unclassified expense, and total expense show undesirable ratios decidedly above the average.

The last two columns of this table are shown graphically in Figure 4.

RELATIVE INFLUENCE OF THE VARIOUS FACTORS

The question remaining to be answered is, what is the relative influence of the different factors studied upon the net gain? On the assumption that that factor, variations in which are associated with the greatest fluctuation in net gain, will most influence the net gain, Table XVIII is presented.

TABLE XVIII

HIGHEST AND LOWEST NET GAINS, AND THE SPREAD BETWEEN THEM, AS REVEALED BY CLASSIFYING THE STORES ON THE BASES SPECIFIED

Basis of classification	Ratio of net gain to gross sales		Difference
	Highest	Lowest	
	Per cent	Per cent	Per cent
Net gain	7.6	1.2	6.4
Expense	6.1	0.7	5.4
Inventory	6.0	1.3	4.7
Unclassified expense	6.2	2.9	3.3
Labor	5.6	2.8	2.8
Indebtedness	5.9	3.3	2.6
Average gross sales	5.4	3.4	2.0
Capital	5.9	4.1	1.8

This table is compiled from Tables XV and XVI and consists of the highest and lowest net gains resulting from the classification in Tables V to XII inclusive, together with the difference in each case between the highest and lowest net gains. The highest and lowest average net gains resulting from the classification on basis of net gain itself (Table V) are included to serve as a basis of comparison. It will not do, of course, to draw too positive conclusions from this table. To some extent the differences between the highest and lowest

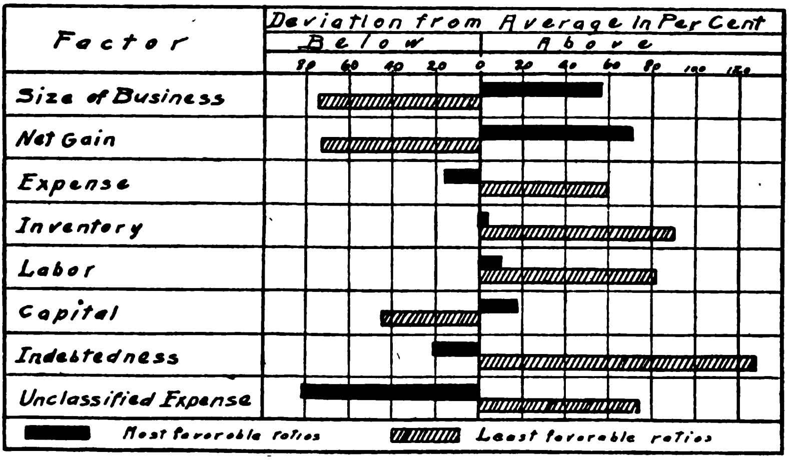

Fig. 4. Comparison of Most Favorable and Least Favorable Ratios of Specified Factors to Gross Sales, With Average of All Stores

net gains in the several classifications are due to the more or less accidental result of the limits of the various groups adopted for the purpose of classifying stores according to each basis. For example, if, in Table VII, the number of classes had been four instead of five, had the lowest class limit been fixed at 9 per cent and the highest at 15 per cent, the averages for net profit would doubtless have been different, and would probably have shown a smaller spread. However, the class limits in the several tables have been so chosen that it is believed conclusions of some importance can be drawn from the comparison in Table XVIII.

The fact that the greatest difference between the highest and the lowest net gain is found in connection with the classification according to the expense ratio leads to the conclusion that this factor is capable of exerting the greatest influence upon net gain. That is, net gain varies more directly with changes in the ratio of expense to gross sales than with changes in any of the other factors. The ratio of inventory to sales, roughly measuring the rate of turn-overs, is next in rank, followed by the ratios of unclassified expense, labor expense, and indebtedness to sales, size of business, and lastly by the ratio of capital to gross sales.

The difference between the highest and lowest net gains resulting from each of the different classifications may be regarded from another viewpoint, i. e., they measure the degree of risk associated with the different factors. The conclusions would, of course, be the same; the greatest risk to the welfare of the enterprise is associated with the factor of expense, a lesser degree with the factor of inventory, and so on to the end of the list.

COMPARATIVE EFFICIENCY OF COÖPERATIVE AND OTHER STORES

No attempt has been made by this Division to study the relative efficiency of coöperative stores in Minnesota as compared with privately owned stores. Possibly the fact that the number of coöperative stores is comparatively small and increasing but slowly, and the further fact that there have been a considerable number of failures of such stores, indicate that at least in most cases the coöperative store is not more efficient or economical than the privately owned store. As already stated, the coöperative store is popular and successful usually only where the private stores have been inadequate or extortionate. In other words, the advantage to the patrons ordinarily consists in saving an excess of profits demanded by the retailer over normal competitive profits.

In order for coöperative stores to become general in a state like Minnesota, it would be necessary for them to prove themselves more efficient than privately owned stores, for in most communities the profits of the latter can not be considered excessive. The mere fact that a store is coöperative does not in itself tend to promote efficiency in management; if anything the tendency is in the other direction. The possibilities of reducing expense through coöperative stores must lie chiefly in bringing about larger scale operation than prevails for privately owned stores and in eliminating those expenses which are due to competition itself. If all the people of a community should join in patronizing a single coöperative store, the duplication of expense which results from division of business among many small establishments might be prevented. The certainty of continuous patronage would also tend to reduce expenses, while needless advertising and other unnecessary costs of competition would disappear. Of course there would be danger that such an establishment, because not subject to the spur of competition, would grow inefficient.

As stated elsewhere, the very marked success of coöperative merchandising in Great Britain and certain other European countries has largely been due to federation and extension of the coöperative principle to the wholesaling business and even to the manufacture of the commodities which the stores handle. There seems to be no immediate prospect that the stores in this state will be able to avail themselves of any such wide-reaching scheme of federation. Efforts to establish such federation in this country have thus far met with comparatively little success.

Doubtless comparisons will be attempted between the ratios presented in this bulletin for coöperative stores and those for other classes of stores that have been compiled by various investigators for other parts of the country. Little real information, however, can be derived from such a comparison because of differences in conditions. There have been no careful studies on a large scale of privately operated stores in the country towns of Minnesota which would be comparable with the coöperative stores.

SUGGESTIONS FOR A COMPLETE CLASSIFICATION OF ACCOUNTS

Ordinarily the accounts of an enterprise can be divided into eight main divisions, four dealing with Real, or Balance Sheet, accounts and four with Nominal accounts, also sometimes termed Income and Expense, or Profit and Loss accounts. These divisions are as follows:

I Real accounts:
  1. Fixed assets
  2. Current, or floating, assets
  3. Trade liabilities
  4. Capital

II Nominal accounts:
  5. Trade revenue
  6. Trade expenditures
  7. Financial revenue
  8. Financial expenditures

Altho in this discussion we are primarily interested in a classification of expenses, coming logically under one of the subdivisions of Division 6, a complete outline is here presented. The accounts given in the following merely serve as an illustration of what some of the successful enterprises are doing. Modifications to meet the needs of individual cases can readily be made by contracting or expanding the classification or by substituting the necessary accounts.

1. *Fixed assets.*—Under this division would be classed accounts with those assets which ordinarily are least readily converted into cash. The accounts suggested are: (a) Real estate; (b) Buildings; (c) Equipment. Because of the fact that buildings are so intimately associated with the land, the first two are sometimes combined under Real estate and Buildings.

2. *Current, or floating, assets.*—As the name implies, this division contains accounts with cash and such other assets as are readily converted into cash, i. e., (a) Cash on hand; (b) Cash in bank; (c) Notes receivable; (d) Accounts receivable; (e) Merchandise inventory, by departments or general classes of merchandise, as groceries, grain, produce, flour and feed, etc.; (f) Furniture and fixtures.

3. Trade liabilities.—Under this heading are grouped accounts with liabilities incurred or resulting in the regular course of trading, such as (a) Trade notes payable; (b) Trade accounts payable.

4. *Capital.*—The following accounts come under this division: (a) Capital stock; (b) Borrowed, or note capital; (c) Sinking fund; (d) Surplus; (e) Promotion; (f) Stock dividends; (g) Trade dividends; (h) Profit and loss.

5. *Trade revenue.*—Under this division it is desirable to open accounts with the different kinds of activities engaged in, departments conducted, or classes of goods handled. The subdivision here will be governed by the kinds of goods handled, the size of the business, and the character of information which it is desired to obtain. Where several unrelated classes of goods are handled, or where activities of various kinds are engaged in, it is highly desirable from a managerial viewpoint to know which departments or activities are profitable and which are not. An account for Discount gained should also be included in this division.

6. *Trade expenditures.*—Expenditures on account of Merchandise purchases, Operation, and Maintenance are charged to accounts under Trade expenditures.

The accounts opened for Merchandise purchases would correspond to those opened under 5. An account for Trade discount lost would also be opened here.

Operation and maintenance is without question the most important subdivision in the classification here presented, as it embraces what is generally included under the heading Expenses. From an economic point of view the existence of a coöperative or other enterprise is justified only if it can perform the services it undertakes at a cost not greater than that at which such services can be performed by other forms of organizations. Not only is it desirable to know the cost of operation for purposes of comparison, but, as previously stated, this information in detail is essential to secure efficient management. Here, as in other parts of this classification, the nature and size of the business and the character of information desired must determine the extent to which the subdivision of accounts can be carried. In nearly all cases, however, it will be found desirable and practicable to open the following accounts:

1. Salary of manager
2. Other office salaries
3. Labor
4. Interest (Trade notes)
5. Rent
6. Insurance
7. Freight and drayage
8. Delivery
9. Advertising
10. Postage
11. Stationery and printing
12. Unclassified

In addition to the above, expenditures for maintenance should be subdivided according to their origin.

7. *Financial income.*—Revenues derived from loans or investments from the funds of the association would be recorded here under Interest gained, or Investments.

8. *Financial expenditures.*—Interest on borrowed, or note capital, should be kept separate from interest on trade notes. Expenditures on account of borrowed capital would be recorded here under a suitable heading.

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The University of Minnesota

AGRICULTURAL EXPERIMENT STATION

A FARM MANAGEMENT STUDY IN SOUTHEASTERN MINNESOTA

FACTORS INFLUENCING PROFITS

BY

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SUMMARY

The area surveyed consists of four townships in the eastern part of Rice County, Minnesota. From this area four hundred useful records for 1912-1913 were obtained. The farms averaged 137 acres in size and $14,401 in value. Of the total investment, 82.6 per cent was in land and buildings and the rest in livestock, machinery, feeds, and supplies. The average value of the land was $89 per acre.

The average labor income on the farms surveyed was $319. Of the 400 farms, 25.3 per cent made minus labor incomes; 35.7 per cent made labor incomes varying from $100 to $400; 32.8 per cent made labor incomes from $400 to $1,000; and 6.2 per cent made labor incomes of more than $1,000. Both the highest and lowest labor incomes were found on farms with a business of more than average size for the area.

The men averaged 249 days of productive work per year and the horses, 81 days. The value of the machinery investment per crop acre ranged from $8 on the smaller farms to $4.06 on the larger farms, while the average for all farms was $5.84. The average cost of man and horse labor was $11.94 per crop acre. There was an average of 4.3 work horses and 1.55 men per farm. On an average, one man cared for 53.9 acres of crop and 11 units of productive livestock. A horse cared for 20.9 acres of crops.

On farms where less than 30 per cent of the receipts were from cash crops, higher labor incomes were made than on farms where a larger proportion came from this source. On farms where more than 50 per cent of the receipts came from cash crops, the operators made an average labor income of $178. Farmers with less than six acres of land for each unit of productive livestock showed higher average labor incomes than those with more than six acres for each unit.

Five factors were found to be important in obtaining satisfactory labor incomes: (1) size of farm; (2) crop yields per acre; (3) returns per unit of productive livestock; (4) number of days of productive labor annually accomplished per man; and (5) number of days of productive labor annually accomplished per horse.[1] Twenty-six farmers with these factors as large as the average or larger, made labor incomes averaging $947. Forty-seven farmers with none of these factors above the average made labor incomes averaging minus $10.

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[1] **A day's labor is the average amount accomplished in a day of ten hours.**

A FARM MANAGEMENT STUDY IN SOUTHEASTERN MINNESOTA

By Andrew Boss, A. H. Benton, and W. L. Cavert

INTRODUCTION

Whether or not farmers are making as large profits as they should from the operation of their farms has been much discussed recently. Few farmers keep records which are sufficiently accurate or comprehensive to be of any value in answering the question. With the development of the farm management survey as a method of studying the farm practices and business principles of individual farmers, however, it has become possible to measure the returns from farming for a community as a whole and to compare the profits obtained by the individual farmers composing the community. In this way it is possible to learn not only the profits from farming but the type of farming that is paying the largest profit. It is also possible to learn which farmers in a community are following the best practices in the organization and management of their farm business. The farm management survey has, in fact, become the commonly accepted method of determining the labor income of a farmer or of the profits from farming in a community. While the data obtained in such surveys are based for the most part upon estimates made by farmers individually, from memory, rather than upon accurately recorded business transactions, the method has been shown to be satisfactory and is used as the basis for farm management demonstration work by the United States Department of Agriculture and by various agricultural experiment stations.

The deductions made from this survey do not differ materially from those from similar surveys in other states. The value of the survey to Minnesota farmers lies in the possibility of learning from the data presented the factors of most importance in securing larger returns under the prevailing conditions for the area surveyed. These are believed to be fairly representative of the state as a whole. Using these important factors as ingredients in a recipe and keeping their relative values in mind, it will be possible to so organize the business of any farm as to minimize the risk of serious loss and in many cases to insure a permanent and satisfactory income.

The data presented in this bulletin apply to the crop year of 1912. Since that time no extended investigation of farm profits and the factors affecting them has been made in Southeastern Minnesota. However, the Agricultural Extension Division has been conducting demonstrations in the summarizing of farm records, and a limited number of records show that at present the average farmer is receiving a labor income materially greater than in 1912.

For 1913 to 1916, inclusive, the following data are available:

County	No. of Farms	Average investment	Average labor income
Clay, 1913	65	$14,287	$313
Clay, 1914	62	15,514	414
Clay, 1915	56	16,098	734
Clay, 1916	47	16,050	1,956
Jackson, 1914	57	28,340	335
Jackson, 1915	55	30,798	Minus 230
Jackson, 1916	47	28,166	1,164
Otter Tail, 1914	73	12,742	304
Otter Tail, 1915	52	13,580	760
Otter Tail, 1916	18	17,506	983
Renville, 1914	62	24,500	423
Renville, 1915	55	26,888	328
Renville, 1916	16	27,822	624

An arithmetical average of these figures from Clay, Jackson, Ottertail, and Renville counties shows the average labor income in 1916 to have been $1,132, while in 1914 the average was $369.

The figures indicate that farm profits have been materially increased under war conditions. Altho the average labor income has increased, there is every reason to believe that variations in size of the labor income of farmers in the same community are governed by the same factors as in 1912.

The assistants in the field work were S. B. Cleland, L. Robertson; S. H. Thompson, and F. A. Corniea.

The thanks of the authors and the department are due to the farmers who furnished the records on which the bulletin is based.

PURPOSE

The purpose of this study, was (1) to determine what profits, if any, the farmers were making; (2) to determine the factors that influence and limit the profits, and to learn if possible the relative importance of these factors when applied to individual farms; (3) to obtain data as a basis for definite and concrete suggestions to farmers who feel that their profits might be increased through a modification of their present system of farm management.

DESCRIPTION OF AREA

LOCATION

The survey was made in Bridgewater, Wheeling, Walcott, and Cannon City townships in Rice County. The area surveyed is approximately 40 miles south of St. Paul, 65 miles north of the Iowa line, and 55 miles west of the Wisconsin line. This section of Minnesota is one of the most prosperous and well-established farming districts in the state. In general the public roads are good and the railway facilities excellent. "No part of the county is more than 12 miles from a railroad."[1] Faribault and Northfield, cities of 9,000 and 3,300 respectively, are the important local market and trade centers.

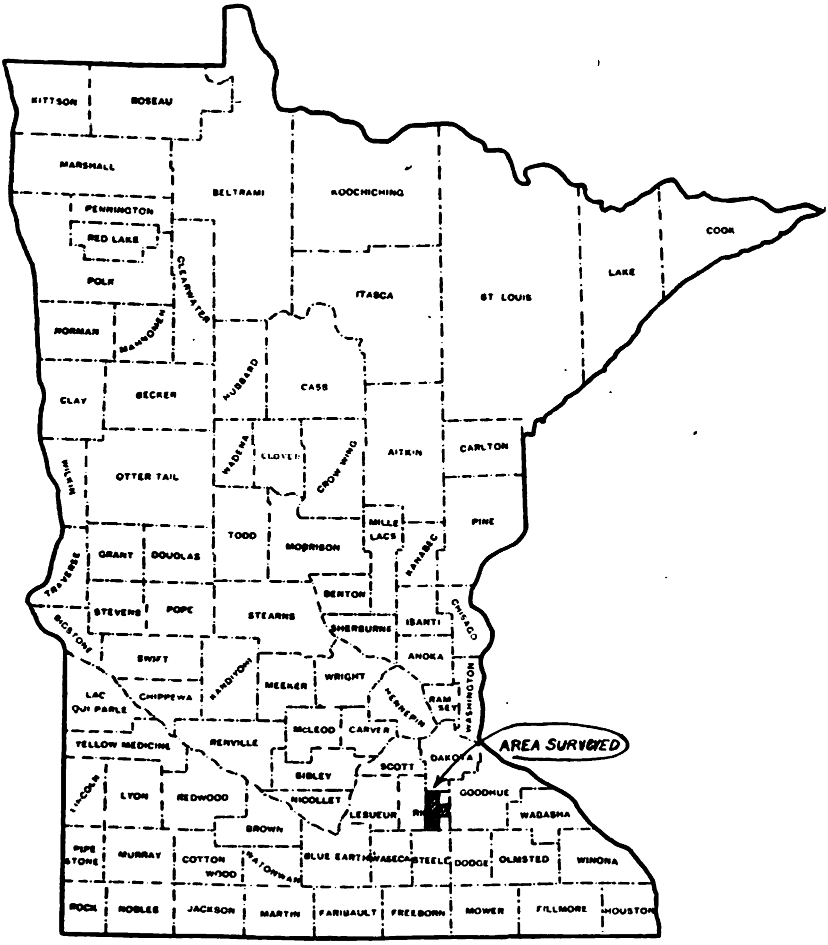

Fig. 1. Area in Which Data Were Obtained

HISTORY

Alexander Faribault established a trading post on Cannon Lake in 1826, and a short time later moved to the site of the city which now bears his name. He was soon followed by other settlers, but they were largely fur traders and no agricultural development occurred until after 1850. In 1853 the Indians gave up their claim to the land and from that time the community developed. Most of the land has now been farmed for 50 years or more. The first immigrants were from other states, but later French Canadians, Germans, Swedes, and Norwegians settled in various parts of the county. While many of the old settlers still cling to the customs and language of their native countries and are more or less bound together in church and racial groups, the rising generation is quite typically American.

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[1] **Soil Survey of Rice County, Minn. U. S. Dept. of Agr. page 8.**

TOPOGRAPHY AND SOIL

As a whole, the area surveyed is rolling and well adapted to general farming. The soil consists of the Carrington series;[2] the Carrington loam and the Carrington silt loam being the two most prevalent types. The Carrington loam is a brownish black loam which grades into yellowish clay at a depth of from 12 to 24 inches.

The Carrington silt loam is grayish black heavy silt loam which grades into brownish clay at a depth of about 15 inches. This brownish clay in turn grades into a yellowish gray at a depth of about 24 inches. The Carrington loam is the most productive under present conditions, because the Carrington silt loam is inclined to be wet and needs much tile drainage for best production.

RAINFALL AND TEMPERATURE

The year April 1, 1912 to April 1, 1913, covered by this survey, varied little from the normal in either amount of precipitation or temperature.[3] Available weather data were recorded for 1912 and 1913 at Farmington, about 15 miles from the area surveyed. The average annual rainfall at Farmington is 29.3 inches, of which 18.9 inches fall in the growing season, May to September, inclusive. In 1912 the rainfall was 26.1 inches, but 20 inches of this fell during the growing season. The average mean temperature at Farmington from May to September, inclusive, is 64.5 degrees, Fahrenheit, and for 1912 the average was 64.3 degrees. The last killing frost in the spring occurred April 29, and the first in the fall, September 26.

CROPS AND CROP YIELDS

The principal crops and average yields per acre for the years 1908 to 1912, inclusive, for this section were: wheat, 15.88 bushels; oats, 39.36 bushels; barley, 27.09 bushels; flax, 10.42 bushels; corn, 38.38 bushels; and hay, 1.61 tons.[4] Crops of lesser importance were winter wheat, rye, millet, alfalfa, and potatoes.

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[2] The Soil Survey of Rice County, Minn. by the U. S. Dept. of Agr. gives a detailed description of the soil, crops, and agricultural conditions in Rice County.

[3] Climatological data, Minn. Sec. U. S. Weather Bureau, U. S. Dept. of Agr.

[4] Peck, F. W. Cost of producing Minnesota farm products, 1908-1912. Minn. Agr. Exp. Sta. Bull. 145, p. 15. 1915.

LIVESTOCK

Livestock raising is well developed, cattle and hogs predominating. This section of Minnesota is especially noted for the good quality of its Holstein cattle. From the vicinity of Northfield a great deal of milk is shipped direct to St. Paul and Minneapolis.

METHODS USED AND TERMS

METHODS

The method of visiting all farms in the selected area was adopted. From 567 farmers visited, 400 usable survey records were obtained. Some farmers refused to give the desired information, others were unable to give it, and some had not operated the farm on which they were located for a full year. In Walcott Township a hail storm destroyed the crops on ten or twelve farms. These were not included in the 400 records used.

Fig. 2. Taking a Farm Management Survey Record

The year April 1, 1912, to April 1, 1913, was abnormal in that there was a decided rise in the price of dairy cattle and a decided drop in the price of grain. Assuming that dairy cows increased in value during the year at the rate of $10 per head, owing to the general rise in the market, a farmer with 15 cows would have been credited with an income of $150 from this source. If this farmer had the same amount of hay, oats, corn, and wheat for seed and feed on hand at the end of the year as at the beginning, he would have been charged with the decline in value of these grains and feeds as a part of his farm expense. In order that the figures might more clearly represent normal conditions, inventory increases and decreases due to market fluctuations were not included as receipts and expenses.

The season was approximately an average one in rainfall and temperature, and crop yields per acre varied little from the normal. By eliminating the seasonal factor of price fluctuation, it is believed that normal conditions were obtained upon which to base any conclusions that are drawn.

In estimating the financial success of a farm business, the fact must be kept in mind that receipts above current expenses consist of the returns from two distinct sources, namely, interest on the investment and income for the farmer's labor and supervision. There are two ways of summarizing the earnings from a farm business: (1) in terms of interest earned on the investment, allowing a reasonable wage for the labor and supervision of the farm operator as a part of the current farm expenses; (2) in terms of the income earned by the farmer above current expenses and interest on the average capital at the market rate for equally desirable investments. The latter method is preferable unless the interest on the investment represents a much larger sum than the market value of the farmer's labor. An additional reason for figuring results in terms of labor income is that it is easier to determine the rate of interest in a community than to determine the value of the time and supervision of each farmer.

TERMS

Farm capital is the amount invested in the farm business, including land, buildings, livestock, machinery, equipment, feeds and supplies. The average farm capital for any year is obtained by adding the farm capital at the beginning of the year and at the end and dividing the sum by two.

Farm receipts are the sum of the cash receipts from crops, livestock in excess of purchases, livestock products, outside labor, and miscellaneous items, as wood and gravel. Any increase during the business year in the value of livestock, crops, feeds, or supplies on hand is ordinarily considered a receipt. An increase in land value is not considered a receipt.

Farm expense includes all current expenses connected with the farm business except interest on the farm capital and the value of the operator's time. Money spent for new machinery and for permanent improvements, such as new buildings and tile drainage, in excess of depreciation charges is not included in the expenses or in increase of inventory at the end of the year. All expenses connected with the household, such as clothing and groceries, were considered as personal except the cost of board for farm laborers.

Farm income is the difference between farm receipts and farm expenses.

Family labor income is the farm income minus the interest on the average capital at the current rate of interest for well-secured farm mortgages. For the calculations in this bulletin, 5 per cent has been assumed to be a fair rate. Family labor income represents the return to the operator and his family for work and management. It does not include house rent or the value of the farm products used in the household.

Labor income or operator's labor income is the balance left after deducting from farm receipts the three following items: farm expenses, interest on the average capital at 5 per cent, and unpaid family labor not including the operator's. (See Table I.)

Minus labor income is the sum by which the operator failed to make his farm expenses and 5 per cent interest on the capital invested. In other words a farm operator with a minus labor income has made less than 5 per cent on his investment, and has received nothing for his year's labor except his house rent and such farm produce as was used in the household.

Landlord's percentage on investment is the rate of interest that the landlord receives on invested capital. It is calculated on the landlord's receipts after deducting taxes and other necessary expenses.

A farm is all the land which one man operates as a unit. It may be all owned or all rented, or partly owned and partly rented. The rented land may belong to one or more different landlords.

An owner is one who owns all the land which he operates.

A part owner is one who owns only part of the land which he operates.

A tenant is one who owns no part of the land which he operates.

A landlord is one who owns land operated by another, either as tenant or part owner.

A crop acre is one used for producing some farm crop other than wood or pasture.

A tillable acre is one suitable for some farm crop other than wood or pasture but not necessarily so used.

Animal unit is the basis used in reducing the different kinds of livestock to a common denominator in order to compare the amount of livestock on one farm with that on another. The system commonly used is to regard a mature cow, steer, or horse kept for a year as an animal unit. Two head of growing cattle, two colts, five hogs, ten pigs, seven sheep, fourteen lambs, or one hundred chickens are also regarded as one animal unit, or equivalent to one mature horse or cow in the amount of feed consumed and value of manure produced. The method is valuable in that it gives an approximate method for comparing the return per unit of productive livestock on one farm with that on another, or for comparing the livestock returns per animal unit on different farms or groups of farms. It is recognized that the amount of feed consumed by a horse or cow varies considerably on different farms. Table I shows the final steps in calculating labor incomes.

A labor unit is the amount of labor ordinarily accomplished in 10 hours by a man or in 20 hours by a horse.

FARMS CLASSIFIED ACCORDING TO TENURE

LABOR INCOME

In Table I the farms of the area surveyed have been grouped into three classes according to tenure: (1) those operated by owners; (2) those operated by part owners; (3) those operated by tenants. There were 231 farms in the first class, 109 in the second, and 60 in the third. The average tenant farm of 151 acres represented a combined landlord's and tenant's investment of $14,937. These farms had both a larger investment and a larger acreage than the farms operated by either the owners or part owners. The expenses and receipts of the tenant farmers also exceeded those of the owners and part owners. The average labor income of $474 for the tenants was $5 smaller than that of the part owners but considerably larger than that of the owners, which averaged only $255 per farmer. It will be noted that the owners had both smaller receipts and smaller expenses than either of the other two classes. The landlords received 4.1 per cent of their investment from the part owners and 3.9 per cent from the tenants.

In all of the tables the farms operated by owners, part owners, and tenants have been grouped together and considered as one class. Wherever labor incomes have been calculated, interest at 5 per cent has been charged on the total investment in the farm business, whether that represented only the investment of the operator or the combined investment of the operator and one or more landlords. All items of receipt and expense were considered as if they belonged to a farm owner and were credited or charged to the farm business accordingly. This was deemed advisable in order to make the farms operated by owners, part owners, and tenants comparable as to rental or interest charges. The object was to study the factors that influenced farm profits in general and not the effect of different forms of tenure on farm profits.

TABLE I
AVERAGE OPERATOR'S LABOR INCOME AND LANDLORD'S PERCENTAGE ON INVESTMENT, 400 FARMS

	Farms operated by owners	Farms operated by part owners			Farms operated by tenants			All farms
		Landlord and part owner	Landlord	Part owner	Landlord and tenant	Landlord	Tenant	
Number of farms..	231	109	....	109	60	....	60	400
Average size (acres).	135	129	40	129	151	....	151	135
Average farm capital	$14,636	$13,607	$2,800	$10,807	$14,937	$13,257	$1,680	$14,401
Average farm receipts	$1,602	$1,787	$144	$1,643	$1,844	$704	$1,140	$1,688
Av'age farm expenses	$432	$496	$29	$467	$629	$193	$436	$479
Average farm income	$1,170	$1,291	$115	$1,176	$1,215	$511	$704	$1,209
Interest at 5 per cent on operator's capital	$732	....	....	$540	....	....	$84	$720
Family labor income	$438	....	....	$636	....	....	$620	$489
Value of unpaid family labor except operator's............	$183	....	....	$157	....	....	$146	$170
Operator's labor income............	$255	....	....	$479	....	....	$474	$319
Landlord's percentage on investment.	....	....	4.1	....	....	3.9	....	3.9

As indicated in Table I the rate of interest received by landlords from tenants was 3.9 per cent and from part owners 4.1 per cent. When all farms are grouped together and labor incomes calculated on a 5 per cent basis, the average labor income for the 400 farmers was $319.

INTEREST EARNED ON INVESTMENT AND RISE IN LAND VALUES

The question may justly be raised, why is the rate of interest received by landlords calculated from the rent of the tenants not the one which should be used in making an investment charge against the farm business? Five per cent instead of a rate based on the rent of tenants has been used because well-secured farm loans netted investors from 5 to 6 per cent. The higher rate on farm mortgage loans did not arise from greater risks. Loans secured by first mortgages are safer investments than land, since the former rarely exceed 50 per cent of the value of the land and buildings. Undoubtedly the reason landlords are willing to take a lower rate than that returned by farm loans, is that they expect to more than make up the difference by a rise in land values. That this expectation has been realized in the last decade is evident. According to the 1910 census, the increase in the value of farm lands for the decade 1900-1910 was at the rate of 5.6 per cent interest compounded annually on the 1900 value. Assuming the same rate of increase in land values for the year in which the survey was taken, the land owners received in addition to a rent above current expenses of 3.9 per cent of the value of the investment, an increase of 5.6 per cent in land values, making a total of 9.5 per cent. Gains from rise in land values are more in the nature of returns from speculations than interest earned on investment.

DISTRIBUTION OF CAPITAL AND USE OF LAND

DISTRIBUTION OF CAPITAL

In Table II the amount and distribution of capital for an average farm are given for the area surveyed and also for Rice County. The data show that the farms of the area surveyed differed little from the average farm of Rice County in distribution of capital. Approximately two thirds of the capital was invested in land, one sixth in buildings, and one sixth in livestock, machinery, feed, and supplies. The latter one sixth is frequently called the operating capital.

TABLE II
DISTRIBUTION OF FARM CAPITAL

	Rice County survey		Rice County*	
	Capital	Percentage of total	Capital	Percentage of total
Average farm capital	$14,401	100.0	$9,560	100.0
Land	9,592	65.6	6,390	66.8
Houses	1,217	9.5	1,805	18.9
Other buildings	1,160	8.1		
Livestock	1,632	11.3	1,060	11.1
Machinery	520	3.6	305	3.2
Feeds and supplies	280	1.9	....	....

* Data for Rice County are taken from 1910 census.

The average farm of the survey consisted of 135 acres valued at $14,401. The average farm of Rice County, according to the 1910 census, consisted of 122 acres valued at $9,560. The average value of the farms of the survey in 1913 was considerably higher than that of the farms of Rice County in 1910. This was due in part to the larger acreage of the farms surveyed and in part to the increase in land values between 1910 and 1913.

USE OF LAND

The crop area and tillable area of farms grouped according to size indicate that the percentage of tillable land in crops varied little as the farms increased in size, except in the group where the farms contained more than 280 acres (Table III). In this group both the proportion of tillable land and the area in crops were considerably lower than on the other farms. The average percentage in tillable land was 77.8 and the percentage actually cropped was 65.9.

TABLE III
RELATION OF SIZE OF FARM TO TILLABLE AREA AND CROP ACRES PER FARM

Size of farm	Number of farms	Average area	Average tillable area		Average crop area	
Acres		Acres	Acres	Per cent	Acres	Per cent
1–40.....	25	32	25	78.1	20.0	62.5
41–80.....	94	68	53	78.0	45.0	66.2
81–120....	81	106	82	77.2	71.0	67.0
121–160....	93	149	117	78.7	99.3	66.6
161–200....	47	185	145	78.2	121.0	65.5
201–240....	35	228	182	79.8	152.0	66.5
241–280....	15	263	203	77.1	161.0	61.1
281 and over	10	394	263	66.8	229.0	58.1
Average* or total.	400	135	105	77.8	89.0	65.9

* Weighted averages, not averages of groups.

Of the land suitable for crops, 11.9 per cent was either used for pasture or was idle. The proportion of farm receipts from different sources (Table IV) indicates that on an average about one third was obtained from crops, one third from livestock, and one third from livestock products. The small farms received a slightly larger percentage of their receipts from livestock and a slightly smaller percentage from crops than the larger farms.

TABLE IV
DISTRIBUTION OF RECEIPTS, 400 FARMS

Size of farm	Number of farms	Crops	Livestock	Livestock products	Miscellaneous
Acres		Per cent	Per cent	Per cent	Per cent
1–40.................	25	30.1	28.2	33.7	8.0
41–80.................	94	27.2	31.4	35.4	6.0
81–120.................	81	25.7	33.3	38.8	2.2
121–160.................	93	32.7	34.4	31.3	1.6
161–200.................	47	31.2	33.8	32.2	2.8
201–240.................	35	36.7	26.8	32.7	3.8
241–280.................	15	37.3	37.5	25.1	0.1
281 and over.............	10	34.3	31.0	27.6	2.1
Average* or total.....	400	31.5	32.6	33.1	2.8

* Weighted averages, not averages of groups.

INVESTMENT IN BUILDINGS

Differences in the price of farm land depended more largely on the value of the buildings than on intrinsic land values due to such factors as location or quality of soils. The average value of land and buildings per farm in the various groups ranged from $110 per acre on the small farms to $77 on the large farms. The data in Table V indicate that on the basis of the value of the land without buildings, there was little variation between the large and small farms. When the value of the buildings was deducted, the value of the land ranged from $65 per acre on the small farms to $74 on the large farms. It will be noted that 20 per cent of the real estate value per acre was in the buildings. There was a variation of $33 in the value per acre between the large and small farms when the buildings were included. When the value of the buildings was deducted the variation was only $9 per acre. The investment per acre in buildings on small farms is necessarily large, since certain buildings are required on all farms regardless of size. There must be a dwelling-house and buildings to shelter livestock and farm produce whether the farm is large or small, and the cost of satisfactory buildings for small amounts of livestock or farm produce can not be reduced in proportion to the amount to be sheltered.

TABLE V

RELATION OF SIZE OF FARM TO VALUE OF LAND PER ACRE WITH AND WITHOUT BUILDINGS, 400 FARMS

Size of farm	Number of farms	Value of buildings per acre		Value of land per acre without buildings		Value of land per acre including buildings	
Acres			Per cent		Per cent		Per cent
1-40.......	25	$36	32.7	$74	67.3	$110	100
41-80.......	94	24	26.1	67	73.9	91	100
81-120......	81	18	20.9	67	79.1	85	100
121-160......	93	18	20.0	72	80.0	90	100
161-200......	47	17	18.8	74	81.2	91	100
201-240......	35	16	17.6	74	82.4	90	100
241-280......	15	14	16.7	70	83.3	84	100
281 and over..	10	12	15.6	65	84.4	77	100
Average* or total.....	400	$18	20.0	$71	80.0	$89	100

* Weighted averages, not averages of groups.

This makes the building investment per acre large on small farms and in turn demands larger returns per acre if profits are to be made on the crops raised. A conservative estimate of the interest, depreciation, repairs, and insurance amounts to from 6.5 to 7.5 per cent of the value of building investments. At 7 per cent the building investment of $36 per acre (Table V) on the small farms would bring a building charge per acre of $2.52 as compared with 84 cents on the largest farms with a building investment of $12 per acre.

TABLE VI

RELATION OF SIZE OF FARMS TO VALUE OF DWELLING-HOUSE AND OTHER BUILDINGS, 400 FARMS

Size of farm	Number of farms	Average capital in buildings	Average value of dwelling-house	Average value of other buildings
Acres				
1-40.................	25	$1,163	$724	$439
41-80.................	94	1,615	982	633
81-120.................	81	1,881	953	928
121-160.................	93	2,606	1,348	1,258
161-200.................	47	3,171	1,490	1,681
201-240.................	35	3,596	1,561	2,035
241-280.................	15	3,693	1,792	1,901
281 and over............	10	4,608	2,304	2,304
Average* or total.....	400	$2,377	$1,217	$1,160

* Weighted averages, not averages of groups.

The larger farms not only had more invested in general farm buildings, but they also had more expensive dwellings (Table VI). On farms of over 80 acres the amount invested in dwellings and in other buildings was nearly equal. There was quite a decided increase both in value of dwellings and in the value of other buildings on farms of more than 120 acres as compared with those of less than 120 acres. The family was more comfortably housed on the larger farms than on the smaller.

THE FARMER'S INCOME

LABOR INCOME

Distribution of labor incomes according to size of farms shows that neither very high nor very low labor incomes were made on the smaller farms (Table VII). This table also shows that both high and low labor incomes were made on farms of more than average size. No farmer made a labor income of over $1,500 on a farm of less than 160 acres. Twenty five and three tenths per cent or approximately one fourth of the 400 farmers made minus labor incomes, in other words they received less than 5 per cent on their investment and nothing for their own labor except a house to live in and that part of the family living which came from their farm products. There were 35.7 per cent or, in round numbers, 36 out of each 100 farmers, who made average labor incomes ranging from $100 to $400 per year. In round numbers, 33 farmers out of each 100, or 32.8 per cent, made average labor incomes varying from $400 to $1,000.

TABLE VII
DISTRIBUTION OF LABOR INCOMES, 400 FARMS

Size of farm	Number of farms	Labor income										
		$-500 or less	$-499 to -200	$-199 to 0	$1 to 200	$201 to 400	$401 to 600	$601 to 800	$801 to 1,000	$1,001 to 1,500	$1,501 to 2,000	Over $2,000
Acres												
1-40	25	.....	.....	3	10	9	3	.....	.....	.....	.....	.....
41-80	94	.....	3	18	23	18	17	12	3	.....	.....	.....
81-120	81	.....	8	8	8	20	14	11	7	4	.....	1
121-160	93	6	11	8	20	10	7	18	8	5	.....	.....
160-200	47	3	5	5	8	7	7	6	1	1	2	2
201-240	35	2	8	2	4	2	3	6	2	5	1	.....
241-280	15	3	1	3	1	2	.....	1	2	2	.....	.....
281-400	6	.....	1	.....	.....	1	.....	2	.....	2	.....	.....
Over 400	4	1	2	.....	.....	.....	.....	.....	1	.....	.....	.....
No. of farms	400	15	39	47	74	69	51	56	24	19	3	3
Percentage of total	100	25.3			35.7		32.8			6.2		

FARM INCOME

A large proportion of the farmers made very low labor incomes; 61 per cent received a labor income of less than $400. Many of those falling in the 61-per-cent class, however, were saving money each year. This was possible because the income of a farmer includes house rent, a considerable part of the food and fuel for the household, and interest on his investment, in addition to his labor income. The income of some farmers was further increased by the value of the unpaid labor performed by other members of the family. The total income of one farmer is given as an illustration (Table VIII). This farmer, with a family of five persons and an investment of $24,000, made a labor income of $311 and a total income of $1,965. A frugal family of five persons in the country can live comfortably on such an income and save considerable money.

TABLE VIII

A FARMER'S INCOME—LARGE, BUT WITH SMALL PROFITS

House rent ($1,500 house)[5]	$150
Food supplied by the farm[5]	158
Fuel supplied by the farm[6]	34
Interest on an investment of $24,000 at 5 per cent	1,200
Unpaid labor performed by operator's son	112
Operator's labor income	311
Total family income	$1,965

That there was a considerable number of farmers who made fair labor incomes and a few who made large labor incomes, indicates that the low labor incomes were not necessarily the result of unfavorable farming conditions but rather of poor methods and management. If the reason can be determined why some of these farmers made satisfactory labor incomes and others did not, suggestions can be made that will be valuable to farmers with unsatisfactory labor incomes.

SIZE OF BUSINESS

MEASURE OF SIZE

The size of the farm business is a factor which usually very greatly influences the size of the labor income. With other factors the same in a large business as in a small one, the large business will return the greater labor income. If a certain method of operation with a small business returns a given profit, twice as large a business operated in a similar way should give twice as large a profit, provided other factors do not vary. Since farms vary in the amount and value of land and in the amount and value of livestock and equipment, various methods have been used in measuring the size of business. Some of the best measures are (1) total area, (2) crop acres, (3) total capital, (4) operating capital, and (5) amount of productive work accomplished. The effect of size of business on labor income in the Rice County area is very definitely shown when units of productive labor accomplished are used as a measure of size. A unit of productive labor consists of either 10 hours of productive man labor or 20 hours of productive horse labor. Productive labor consists of caring for productive livestock, growing farm crops, making permanent improvements, or of outside labor by farm teams and employees which brings revenue to the farm. Maintenance work, as caring for work horses, repairing buildings and fences, and general upkeep, are not included as productive labor. The hours of productive labor were calculated from Table IX.

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[5] Peck, F. W. Cost of living on Minnesota farms. Minn. Agr. Exp. Sta. Bull. 162. 1916.

[6] Funk, W. C. Value to farm families of food, fuel, and use of house. U. S. Dept. of Agr. Office of Farm Mgmt. Bull. 410. 1916.

TABLE IX

AVERAGE LABOR REQUIRED, IN HOURS, FOR CROPS AND PRODUCTIVE LIVESTOCK*

	Man hours	Horse hours
Hay and alfalfa (each cutting), per acre	10.0	10.0
Small grains, except corn, per acre	15.0	30.0
Corn, all kinds	35.0	60.0
Potatoes, per acre (without special machinery)	120.0	100.0
Apples, per bushel	2.0	0.6
Clover and timothy seed	7.0	9.0
Truck crops, no acreage (each $5 received)	10.0	10.0
Cows, per head	150.0	20.0
Cattle, colts, etc., not stalled, per head	20.0	1.0
Sheep with lambs, per head	5.0	0.5
Brood sows with pigs until weaned	30.0	5.0
Other hogs, per head	5.0	1.0
Poultry, per head	1.5	0.2
Bees, per hive	5.0	....
Miscellaneous: road work, cutting wood, and putting up ice—		
Man labor for each $1.50 received	10.0	....
Man and team labor for each $4 received	10.0	20.0

* Data are based on U. S. Farmers' Bulletin 661, A method of analyzing the farm business, by E. H. Thompson and J. M. Dixon; and on cost accounting records on file in the Division of Agronomy and Farm Management, of the University of Minnesota.

LABOR ACCOMPLISHED AND LABOR INCOME

A study of the size of the farm business based on the amount of productive labor accomplished by men or horses indicates a very close relation between the size of business and the labor income. (Table X). The farms on which less than 200 units of labor were annually accomplished returned an average labor income of $97 to the operators. As the number of labor units increased per farm, the labor incomes consistently increased. The labor incomes averaged $605 on the farms where more than 1,000 units of labor were accomplished.

TABLE X

RELATION OF PRODUCTIVE LABOR UNITS PER FARM* TO LABOR INCOME, 395 FARMS†

Labor units per farm	Number of farms	Average number of labor units	Average labor income
200 and under	19	166	$97
201-400	101	327	207
401-600	132	501	267
601-800	73	672	330
801-1,000	41	844	489
1,001 and over	29	1,133	605

* A productive labor unit is either 10 hours of productive man labor or 20 hours of productive horse labor.

† Some factors in the farm business could not be accurately figured on 5 farms. For this reason 395 instead of 400 farms are used in many tabulations.

TOTAL CAPITAL AND LABOR INCOME

There appears to be a fairly consistent relation between the total amount of capital in the farm business and the labor income (Table XI). This relation, however, is not close enough to be of as great importance as labor units in showing the influence of size of business on labor income. Farmers with $5,000 invested in the farm business had an average labor income of $164. With each increase of $5,000 in the amount of farm capital the average size of the labor incomes consistently increased except on the group of farms with $15,000 to $20,000 invested. The farmers with capital averaging $30,406 invested made $635 as an average labor income.

TABLE XI

RELATION OF FARM CAPITAL TO FARM INCOME, 400 FARMS

Total capital per farm	Number of farms	Average size of farms	Average farm capital	Average labor income
		Acres		
$5,000 and under	30	39	$3,829	$164
5,001-$10,000	104	76	7,845	255
10,001-15,000	103	123	12,384	310
15,001-20,000	81	166	17,287	271
20,001-25,000	39	197	21,793	363
25,001 and over	43	270	30,406	635
Average* or Total	400	135	$14,401	$319

* Weighted averages, not averages of groups.

OPERATING CAPITAL[7] AND LABOR INCOME

The relation between the amount of operating capital and the labor income (Table XII) was more consistent than the relation between total capital and labor income. Farmers with less than $1,000 operating capital made an average labor income of $117. As the amount of operating capital increased, labor incomes consistently increased. On farms with an operating capital of $5,000 or more the average labor income was $735. The influence of operating capital on labor incomes was greater than that of the total capital because the former is usually a better indication of the magnitude of the business than the latter.

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[7] The term "Operating capital," as used in this bulletin, includes farm capital invested in livestock, machinery, equipment, feeds, and supplies.

TABLE XII

RELATION OF OPERATING CAPITAL TO LABOR INCOME, 400 FARMS

Operating capital per farm	Number of farms	Average operating capital	Average labor income
$1,000 and under	50	$727	$117
1,001-$1,500	57	1,226	208
1,501- 2,000	74	1,743	246
2,001- 2,500	64	2,263	275
2,501- 3,000	49	2,761	387
3,001- 4,000	52	3,369	392
4,001- 5,000	30	4,389	505
5,001 and over	24	6,203	735
Average* or Total	400	$2,432	$319

* Weighted averages, not averages of groups.

Further study of the data on operating capital in Table XIII shows that the labor incomes increased more rapidly with an increase in the percentage of operating capital than with an increase in the actual amount of operating capital as shown in Table XII. Farms with less than 10 per cent of the total investment in operating capital showed labor incomes averaging $44. With each 5 per cent increase in the amount of working capital there was a fair increase in the size of the labor income.

On farms with 30 per cent or more of the total investment in operating capital, the average labor income was $780. Some farms that had a high percentage of operating capital may have been handicapped if it consisted of an excessive investment in work-stock and machinery. For the most part the farms suffered from lack of working capital rather than from the use of too much of it. Operating capital on Rice County farms from the standpoint of its proportion of the total capital, is in a large measure an indication of the intensity of the farming practiced. In this region one of the principal methods of intensifying the farm business was to increase the amount of livestock in proportion to the acreage. The investment in real estate was increased only by such permanent improvements as were necessary to care for the larger amount of livestock. An increase in the amount of livestock, therefore, increased both percentage and amount of operating capital. The amount of the operating capital invested in livestock was 69.5 per cent. It is evident that the effect of operating capital on labor income depended as much upon its use as upon the amount or its proportion of total capital.

TABLE XIII

Relation of Percentage of Operating Capital per Farm to Labor Income, 400 Farms

Percentage of operating capital per farm	Number of farms	Operating capital	Percentage of operating capital	Labor income
Under 10	18	$1,188	8.1	$44
10-14.9	115	1,961	12.6	207
15-19.9	166	2,619	17.5	322
20-24.9	71	2,661	23.6	399
25-29.9	23	2,989	27.1	480
30 and over	7	3,489	35.8	780
Average* or Total	400	$2,432	16.8	$319

* Weighted averages, not averages of groups.

FARM AREA AND LABOR INCOME

As the total area per farm increased there was a steady increase in the farm income but not in the labor income (Table XIV). The farm income would naturally increase with a larger area, for under ordinary conditions there would be a larger business. Additional area up to 120 acres tended to increase the labor income of the operator. Beyond this point the average labor income was lower in several groups.

TABLE XIV

Relation of Size of Farm to Labor Income, 400 Farms

Size of farm	Number of farms	Average size of farms	Average farm income	Average labor income
Acres		Acres		
1-40	25	32	$380	$165
41-80	94	68	655	274
81-120	81	106	940	388
121-160	93	149	1,088	284
161-200	47	185	1,385	373
201-240	35	228	1,557	355
241-280	15	263	1,794	494
281 and over	10	394	2,658	317
Average* or Total	400	135	$1,209	$319

* Weighted averages, not averages of groups.

The relation between crop acres (as a measure of size) and labor income was slightly more consistent than the relation between total area and labor income (Table XV). The largest average labor incomes were on those farms with from 131 to 150 acres of land in crops. The lowest labor incomes were on those with the smallest acreage of crops, averaging only 20 acres per farm. Neither total area nor total crop acreage is a satisfactory measure of size unless all farms raise the same kind and relative amount of crops, and keep the same kind and relative amount of the various classes of livestock. An illustration based on Table IX shows that the man who grows 50 acres of corn needs as much labor as the man who grows 100 acres of small grain or 200 acres of hay.

TABLE XV

RELATION OF CROP ACRES PER FARM TO LABOR INCOME, 400 FARMS

Crop acres	Number of farms	Average crop acres	Average labor income
Under 30	36	20	$181
31-50	59	42	260
51-70	82	60	329
71-90	47	82	369
91-110	55	99	210
111-130	51	121	353
131-150	30	143	543
151-170	14	158	473
171-190	13	180	412
191 and over	13	224	242
Average* or Total	400	89	$319

* Weighted averages, not averages of groups.

A SATISFACTORY MEASURE OF SIZE

Where figures are available for the average labor requirements for growing crops and for caring for livestock, the amount of labor accomplished is the most satisfactory measure of size. Inasmuch as size of business is a factor that influences the amount of profits, there should be a definite relation between the number of units of productive labor annually accomplished and the labor income. The data in Table X bear out this reasoning. In the 400 records obtained, only 29 showed labor incomes of $900 or more. Of these 29 farms, only two had less than 555 units of productive labor, the average for the 400 farms. The average number of productive labor units for these 29 farms was 891, or 59.6 per cent above the average for the 400 farms. The relation between size of farm business and labor income as already discussed is presented graphically in Figure 3.

INCREASING THE SIZE OF BUSINESS

In general, there are two means by which the size of a farm business may be increased. (1) The acreage in crops may be increased either by the purchase or rental of additional land, or by improving land already owned by means of clearing or drainage. (2) The farming may be made more intensive by growing a larger acreage of cultivated crops, as corn or potatoes, which require more labor per acre than uncultivated crops. The amount of labor may be increased by keeping more livestock.

The course which a farmer who wishes to increase his business should pursue will depend on the size of his farm and the intensity with which he operates it. If the farm is small and already intensively operated, an increase in acreage is ordinarily the logical course to follow. On the other hand, if the farm is large and not intensively operated, an increase in the acreage of cultivated crops and in the amount of livestock kept, will likely prove the more profitable.

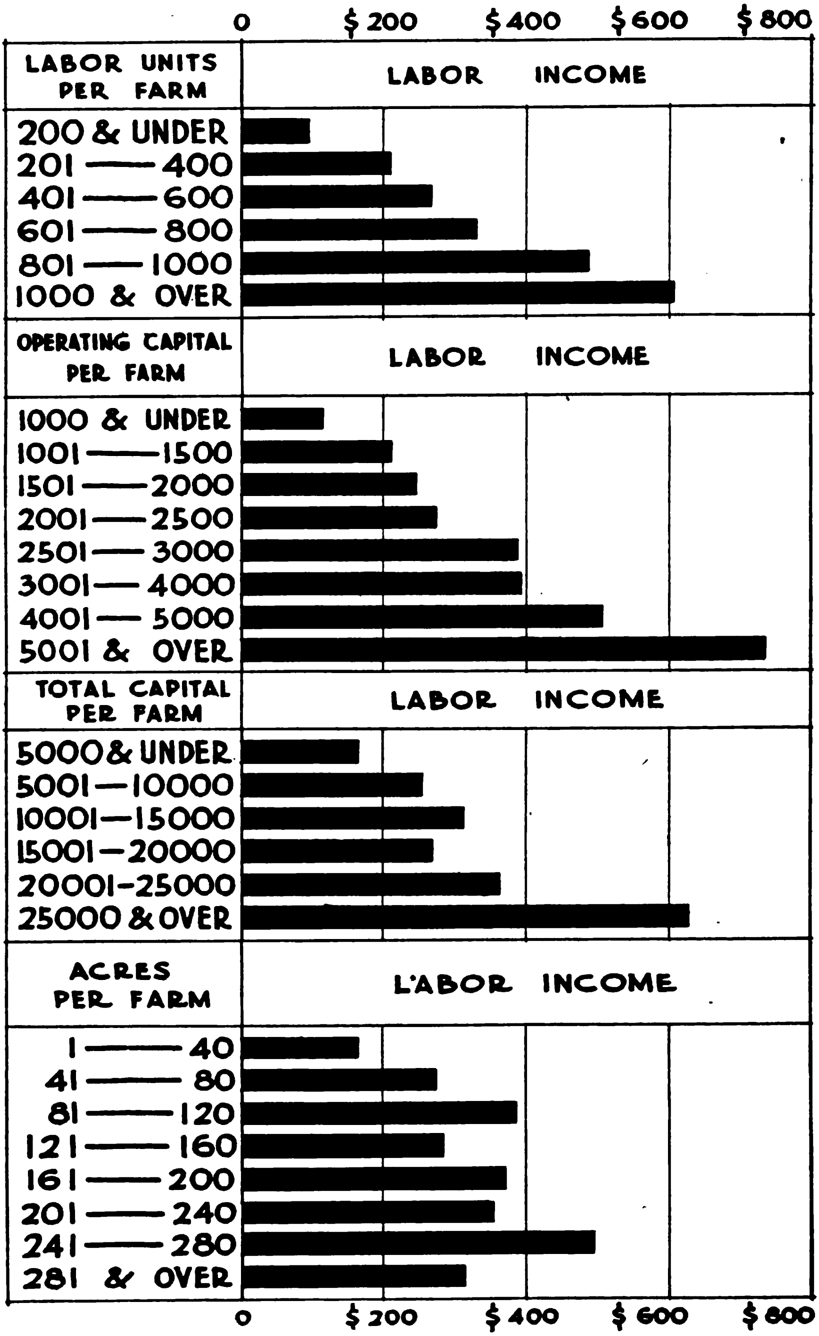

Fig. 3. Relation of Size of Business to Labor Income

RELATION OF CROPS AND LIVESTOCK TO FARM BUSINESS

SIZE OF FARMS AND YIELDS PER ACRE

The yields per acre of the leading crops on the farms grouped according to size are shown in Table XVI. There was no material variation in the crop yields as expressed by crop index on the farms of more than 40 acres in size.[8] On farms of 40 acres or less, the crop yields were 8 per cent higher than the average. While the small farms had the highest average crop yields per acre, they did not have as high yields per acre of oats or barley as were found in several of the larger farm groups.

TABLE XVI

RELATION OF SIZE OF FARM TO AVERAGE CROP YIELDS PER ACRE, 400 FARMS

Size of farm	Number of farms	Corn for grain	Spring wheat	Oats	Barley	Timothy and mixed hay	Crop index*
Acres		Bushels	Bushels	Bushels	Bushels	Tons	
1–40.......	25	46.6	18.0	35.5	28.9	1.74	108
41–80.......	94	42.3	16.0	37.3	29.2	1.58	102
81–120......	81	44.1	16.7	38.6	24.7	1.43	100
121–160......	93	43.7	15.7	41.5	27.2	1.33	100
161–200......	47	41.1	16.4	39.5	31.9	1.41	101
201–240......	35	40.8	14.8	38.3	27.5	1.56	97
241–280......	15	35.3	16.6	39.9	28.3	1.21	96
281 and over..	10	43.8	15.0	40.0	30.6	1.36	102
Average† or total.....	400	42.0	16.0	40.0	28.0	1.40	100

* One hundred equals the average crop yields of the area surveyed.

† Weighted averages, not averages of groups.

There was little variation in the proportionate acreage of the different crops raised on the farms of different sizes except on the largest and smallest farms (Table XVII).

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[8] The crop index is a percentage figure obtained by considering the average crop yields of a locality as a 100 per cent yield. A crop index of 92 for a farm or for a group of farms means that the average yields per acre were 92 per cent of the average of all the farms of that locality. An example of the method used in determining the crop index is given below.

Crop	Area in crops on given farm	Total yield on given farm		Average yield for all farms		Area that would have been required to produce the same amount with average yields
	Acres					Acres
Corn............................	10	504 Bu.	÷	42 Bu.	=	12
Wheat............................	25	320 Bu.	÷	16 Bu.	=	20
Oats............................	20	800 Bu.	÷	40 Bu.	=	20
Barley............................	9	240 Bu.	÷	28 Bu.	=	9
Hay............................	20	26 T.	÷	1.4 T.	=	18
Total........................	84					79

(79÷84)×100=94, crop index.

TABLE XVII

RELATION OF SIZE OF FARM TO PERCENTAGE OF CROP AREA IN SMALL GRAIN, 400 FARMS

Size of farm	Number of farms	Average acres per farm	Percentage of crop area in small grain	Percentage of crop area in corn	Percentage of crop area in hay	Percentage of crop area in other crops
Acres						
1–40.....	25	32	19.3	46.6	15.6	18.5
41–80.....	94	68	44.8	26.6	19.9	8.7
81–120....	81	106	48.3	26.9	19.5	5.3
121–160....	93	149	51.8	21.2	21.7	5.3
161–200....	47	185	51.9	23.1	19.9	5.1
201–240....	35	228	55.7	20.1	18.7	5.5
241–280....	15	263	49.8	23.2	18.6	8.4
281 and over	10	394	58.9	13.7	23.4	4.0

"Small grain" includes wheat, oats, barley, rye, and flax. Under the heading "Other crops" are grouped potatoes, grass seed, truck crops, and any others not found in the first three classes. On the farms of 40 acres or less there was, as was to be expected, an emphasis on the production of corn in proportion to the production of small grain. There were nearly three times as many acres in corn as in small grain. As the size of the farms increased there was a tendency to increase the proportion of land sown to small grain, and to make a corresponding decrease in the area planted to corn. The difference was not striking, however, until the group of largest farms was reached. The farms of this group showed nearly three times as many acres in small grain as in corn.

CROP YIELDS PER ACRE AND LABOR INCOME

There was a consistent gain in the labor income with the increased crop yields per acre (Table XVIII), but the crop yields under the system of farming followed in this area seem to have been a less important factor than returns per unit of livestock (Figure 5). This was to be expected in a region where livestock is the principal market for the crops raised. The highest yielding crops fed to livestock of low production give smaller farm profits than low yielding crops fed to highly productive livestock. The variation in the average crop yields per acre from one farm to another is ordinarily much less than the variation in the returns per unit of livestock. It is not uncommon to find farms where the livestock is twice as productive as the average. Other farms will be found where it is only one half as productive as the average. On the other hand few farms are found which have crop yields one half higher or more than one third lower than the average of the locality. The explanation without doubt lies in the fact that crop production is to a large extent dependent on climate and soil conditions beyond human control, while livestock production is much more directly under the control of the farmer. As a result the possible reward for skillful husbandry is greater in the case of livestock than of crops. Data from regions in western Minnesota indicate that the yield per acre is one of the outstanding factors in determining labor incomes where crops are largely disposed of for cash instead of being fed to livestock.

TABLE XVIII
Relation of Crop Yields per Acre (Crop Index) to Labor Income, 395 Farms

Crop index*	Number of farms	Average crop index†	Labor income
80 and under	51	69	$37
81–90	57	87	87
91–100	110	96	319
101–110	67	103	416
111–120	60	115	467
121 and over	50	133	504

* One hundred equals the average of the area.

† The average crop indexes are not weighted averages but are obtained by using the crop index of each farm as a unit.

RECEIPTS PER COW AND LABOR INCOME

The returns from sales of dairy products per cow where six or more milch cows are kept are given in Table XIX. The farms grouped in this table according to the sales of dairy products per cow show average labor incomes of $93, $154, $320, $457, $632, $724, and $985, as the sales of dairy products per cow increased by $10 intervals from $30 or less in the first group to $80 or more in the last group. It will be noted that the average labor income of $985 for the group having average receipts of more than $80 per cow is more than three times as much as the average labor income of $319 for all the farms of the area. The importance of high productivity is further emphasized when it is noted that there was little variation

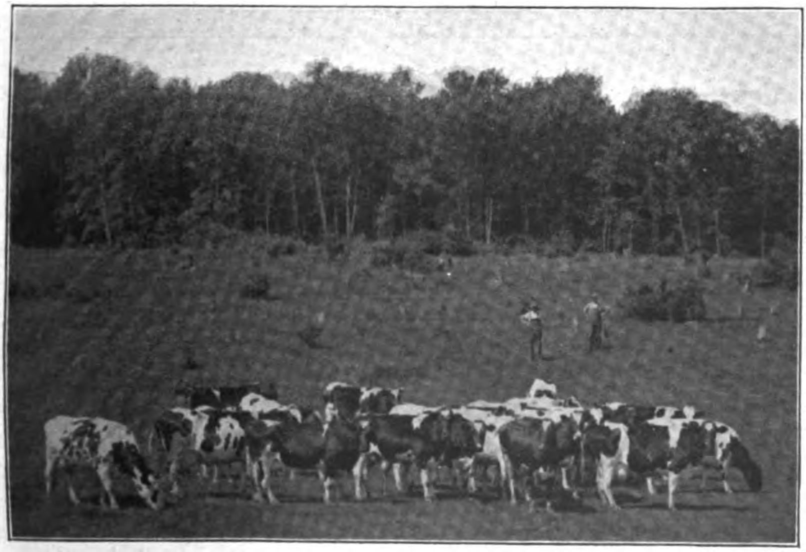

Fig. 4. Good Dairy Cattle a Profitable Investment on Many Farms

in the average number of dairy cows per farm (Table XIX). In round numbers, all the groups of farms averaged between 10 and 12 dairy cows except one group, which had 16 cows per farm. The striking relation between the returns per cow and the labor income indicates that dairy farmers can scarcely give too much emphasis to increasing the production of their dairy herds.

This increased production can be obtained by giving more attention to balancing the dairy rations, by using better dairy sires, and by disposing of the cows which are unprofitable as indicated by the individual milk records and butterfat tests. Several of the most successful farmers in the area surveyed were using all of these means in making their dairy herds profitable.

TABLE XIX

RELATION OF SALES OF DAIRY PRODUCTS PER COW TO LABOR INCOME, 316 FARMS WHERE 6 OR MORE MILCH COWS WERE KEPT PER FARM

Sales of dairy products per cow	Number of farms	Average number of cows per farm	Average labor income
$30 and under	74	9.8	$93
31–40	69	10.9	154
41–50	69	11.9	320
51–60	45	11.4	457
61–70	27	15.6	632
71–80	20	11.0	724
81 and over	12	10.7	985

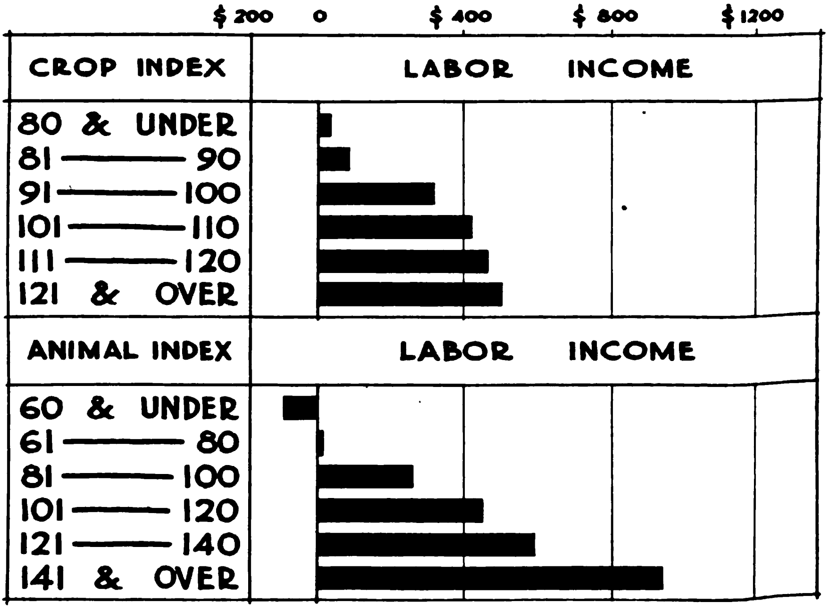

Fig. 5. Relation of Crop Yields per Acre and Returns per Unit of Productive Livestock to Labor Income

RETURNS PER UNIT OF PRODUCTIVE LIVESTOCK AND LABOR INCOME

The size of labor incomes was largely determined by the returns per unit of all productive livestock (Table XX and Figure 5). The animal index was used as a measure of the average returns from productive livestock.[9] The large and consistent increase in the labor income as the animal index increased emphasizes the importance of high returns from productive livestock. The farms with productive livestock returning less than 60 per cent of the average for the area surveyed have average labor incomes of minus $49. In other words, these farms failed by $49 to pay farm expenses and 5 per cent on the investment, with nothing allowed for the operator's labor. As the animal index increased, average labor incomes rapidly increased. The farms with an animal index of 141 or more had an average labor income of $934.

TABLE XX

RELATION OF RETURNS FROM LIVESTOCK (ANIMAL INDEX) TO LABOR INCOME, 395 FARMS

Animal index*	Number of farms	Average animal index†	Average labor income
60 and under	41	49	$-49
61-80	89	72	12
81-100	103	91	266
101-120	69	110	445
121-140	51	129	590
141 and over	42	169	934

* One hundred equals the average of the area surveyed.

† Average animal indexes are not weighted averages but are obtained by using the animal index of each farm as a unit.

MACHINERY, HORSE LABOR, AND MAN LABOR

INVESTMENT IN MACHINERY

In each group of farms there was a consistent increase in the total average value of machinery per farm as the size of the farms increased, but the value of machinery per crop acre consistently decreased (Table XXI). This indicates that farm machinery was used more

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[9] The average receipts per animal unit for each kind of productive livestock were calculated from all the farms of the area. The average receipts per unit for dairy cows were $46; for other cattle, $52; for horses, $111; for hogs, $129; and for poultry, $103. The average receipts per animal unit for each class of livestock were rated as 100 per cent. The animal index is then calculated in the same manner as the crop index. An animal index of 116 for a farm or a group of farms, means that the livestock returns were 116 per cent as compared with the average of the whole area. The method of calculating the animal index is as follows:

	Actual animal units on a given farm	Total returns on given farm		Average returns per animal unit for all farms		Animal units required to give the same returns with average livestock
Dairy cows	13.5	$600	÷	46	=	13.0
Other cattle	20.0	1,185	÷	52	=	22.8
Colts	3.5	425	÷	111	=	3.8
Swine	2.8	525	÷	129	=	4.1
Poultry	1.5	413	÷	103	=	4.0
	41.3					47.7

(47.7÷41.3)×100=116, animal index.

efficiently on the large farms. The smaller farms did not have a sufficient acreage of crops to allow the machinery to be used to its full capacity. Even with a higher machinery value per acre the small farms were usually not so well equipped with labor-saving machinery as the larger farms.

TABLE XXI

RELATION OF SIZE OF FARM TO INVESTMENT IN MACHINERY

Size of farm	Number of farms	Average number of crop acres	Value of machinery per farm	Value of machinery per crop acre
Acres				
1–40	25	20	$160	$8.00
41–80	94	45	332	7.40
81–120	81	71	445	6.26
121–160	93	99	556	5.62
161–200	47	121	662	5.47
201–240	35	152	878	5.78
241–280	15	161	855	5.32
281 and over	10	229	930	4.06
Average* or Total	400	89	$520	$5.84

* Weighted averages, not averages of groups.

In the group of smallest farms, averaging only 20 acres per farm, the machinery investment was $8 per acre. As the farms increased in size the machinery investment per acre decreased. On the farms of largest size, averaging 229 acres, the machinery investment was only $4.06 per acre. This was only a little more than 50 per cent of the value of the machinery per acre for farms of the smallest acreage. The total value of the machinery ranged from $160 per farm on the smallest farms to $930 per farm on the largest. The average value of machinery for all farms was $520. Altho the variation in the machinery investment on different farms is quite large, the opportunity for reducing farm expenses through high efficiency in the use of machinery is not great on the average farm. There was a difference of $3.94 per acre in machinery value between the largest and smallest farms. Assuming that the annual machinery cost is 20 per cent of the inventory value, the saving on the largest farms over the smallest farms, due to lower machinery investment, would have been only 80 cents per acre. This is a small saving as compared to the saving that may be made by more efficient use of man and horse labor.

COST OF LABOR

The high cost of man and horse labor (Table XXII) emphasizes the importance of considering labor costs and getting high returns from labor if profits are to be made from farming. The cost of man and horse labor per crop acre ranged from $8.30 on the largest farms to $32.45 on the smallest farms. The total cost on the average farm with 89 crop acres was $1,062, or $11.94 per crop acre. The figures indicate that the farmers on the small farms had a much more serious proposition in securing profits from their crops than did those on farms of larger size. The relatively high cost of man and horse labor per acre on the small farms made it imperative that more intensive cropping be practiced and higher receipts per acre be obtained than on the larger farms, if proportionately high profits were to be made.

TABLE XXII

RELATION OF SIZE OF FARMS TO COST OF MAN AND HORSE LABOR PER ACRE

Acres	Number of farms	Crop acres	Total cost of man and horse labor*	Cost of man and horse labor per crop acre
1–40	25	20	$ 649	$32.45
41–80	94	45	785	17.45
81–120	81	71	920	12.96
121–160	93	99	1,087	10.98
161–200	47	121	1,368	11.31
201–240	35	152	1,475	9.70
241–280	15	161	1,622	10.08
281 and over	10	229	1,900	8.30
Average† or Total	400	89	$1,062	$11.94

* Total cost of man and horse labor consists of the annual cost of man labor at the rate of $400 per man and horse labor at the rate of $103 per horse. The cost of horse labor is based on figures in Minn. Agr. Exp. Sta. Bull. No. 145, The cost of producing Minnesota farm crops, 1908-1912, by F. W. Peck.

† Weighted averages, not averages of groups.

EFFECTIVE USE OF MAN LABOR

As the farms increased in size, a unit of man labor cared for more acres of crops and a larger number of productive animal units (Table XXIII). In a few instances there was a decrease in either the number of crop acres per man or the amount of productive livestock per man as the size of the farms increased. In no group of farms, however, was there a decrease in both crop acres per man and productive livestock per man as the size of the farm increased. On an average, a unit of man labor cared for 11 units of productive livestock and 53.9 acres of crop. On the farms of 40 acres or less the greater intensity of cultivation explains in part the smaller number of acres and smaller amount of productive livestock cared for per man. It has already been pointed out in Tables XVI and XVII that there was little difference in the character of crops raised or in the yields per acre except on the largest and smallest farms. Leaving out of consideration the farms of 40 acres and less and those of 281 acres and more, the number of crop acres per man increased from 52.3 acres on the group of farms ranging from 81 to 120 acres, to 70 acres on the group ranging from 241 to 280 acres. This increase of 34 per cent in the number of acres farmed per man can only be satisfactorily accounted for on the basis of more efficient use of man labor on the larger farms.

On the basis of the number of days of productive labor annually accomplished per man, the effect of the size of farm on the amount of work accomplished per man is also clearly illustrated in Table XXIII. The men on the farms of 40 acres and less accomplished only 140 days of productive labor per man or 56.2 per cent as much as the average man, while the men on farms of more than 280 acres accomplished 24.5 per cent more than the average. The average number of men per farm was 1.55 and the average number of days of productive work annually accomplished was 249. The average of 1.55 men per farm usually meant one man's time throughout the year and extra help during the active season, equivalent to about six months' labor for another man. The average number of days of productive labor annually accomplished per man increased as the farms increased in area to 280 acres. In the largest-farm group, only ten farms, there was a slight decrease in the number of days of productive work annually accomplished, but it is well within the bounds of probable error and does not affect the general principle. A certain amount of maintenance labor is common to all classes of farms, such as fence repairs, upkeep of buildings, and care of machinery and work animals. This work is not increased proportionately as farms increase in size. The amount of labor on work horses, machinery, buildings, and fence repairs is proportionately less on the larger farms than on the smaller ones.

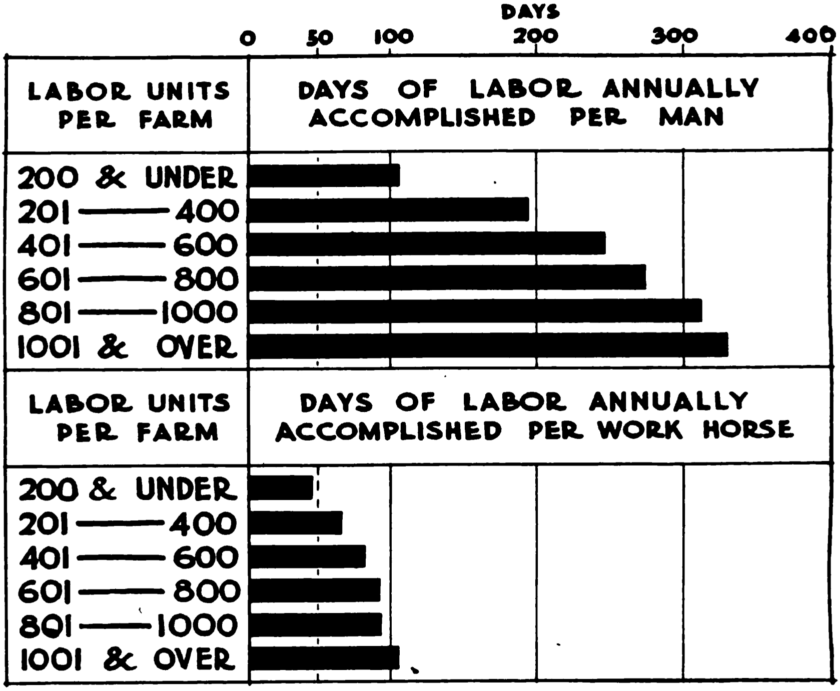

Fig. 6. Relation of Labor Units per Farm to Efficiency of Horse and Man Labor

TABLE XXIII

RELATION OF SIZE OF FARM TO EFFICIENCY OF MAN LABOR ON THE BASIS OF CROP ACRES, PRODUCTIVE ANIMAL UNITS, AND DAYS OF PRODUCTIVE MAN LABOR PER MAN*

Size of farm	Number of farms	Average number of men per farm	Average number of crop acres per man	Average number of productive animal units per man	Days of productive man labor per man per year*
Acres					
1–40	26	1.15	17.4	5.3	140
41–80	93	1.23	36.6	9.1	204
81–120	82	1.36	52.3	11.7	248
121–160	90	1.56	63.5	12.1	263
161–200	46	1.97	61.5	12.9	270
201–240	36	2.05	74.1	13.0	277
241–280	12	2.30	70.0	14.7	312
281 and over	10	2.45	93.5	14.0	310
Average† or Total	395	1.55	53.9	11.0	249

* A day's labor is the average amount of labor accomplished by a man in a day of 10 hours.

† Weighted averages, not averages of groups.

EFFECTIVE USE OF HORSE LABOR

Horse labor was also used more effectively on the larger farms than on the smaller ones (Table XXIV). Considering all the farms, there was an average of 4.3 horses per farm and an average of 81 days of productive labor annually accomplished per work horse. On the farms of 40 acres or less, the average number of productive days of labor accomplished per horse was 52, or 64.2 per cent of the average. The horses on farms of more than 280 acres annually accomplished 97 days of labor per horse, or 20 per cent more than the average. On the basis of the number of acres of crops cared for per work horse, the larger farms also have the advantage.

TABLE XXIV

RELATION OF SIZE OF FARM TO EFFICIENCY OF HORSE LABOR ON THE BASIS OF NUMBER OF DAYS OF PRODUCTIVE HORSE LABOR* AND THE NUMBER OF CROP ACRES

Size of farm	Number of farms	Work horses per farm	Crop acres per work horse	Days of productive horse labor per work horse per year
Acres				
1–40	26	2.1	9.5	52
41–80	93	3.0	15.0	66
81–120	82	3.7	19.1	77
121–160	90	4.4	22.5	82
161–200	46	5.2	23.3	87
201–240	36	6.2	24.5	87
241–280	12	6.6	24.4	98
281 and over	10	7.7	29.7	97
Average† or Total	395	4.3	20.7	81

* A day's labor is the average amount of labor accomplished by a horse in a day of 10 hours. See Table IX.

† Weighted averages, not averages of groups.

SIZE OF BUSINESS AND EFFECTIVE USE OF LABOR

On the basis of the productive work annually accomplished on the various farms, those with the larger business used horse and man labor most effectively (Table XXV and Figure 6). Farms with the larger business, in general have a much better opportunity for obtaining more work from men employed and horses used. However, a large business does not necessarily bring this about. With a farm business requiring two men and at least six horses, economy of man labor can be obtained by the use of four- or six-horse teams in much of the farm work. One man can use a two-horse team for light work and trips to town while the other man can use the four-horse team on the heavy work without interruption. Contrasting the larger business with the smaller one usually found on 40- to 80-acre farms, it is well to note that on the latter there is work for not more than three horses and one man except at harvest-time. Under such conditions it is scarcely possible to get the same efficiency of man and horse labor as on farms where more than one man and four or more horses are needed.

TABLE XXV
RELATION OF NUMBER OF LABOR UNITS* PER FARM TO NUMBER OF DAYS OF PRODUCTIVE MAN LABOR† ANNUALLY ACCOMPLISHED PER MAN, AND OF PRODUCTIVE HORSE LABOR PER WORK HORSE

Labor units per farm per year	Number of farms	Days of productive man labor annually accomplished per man	Days of productive horse labor annually accomplished per work horse
200 and under	19	107	46
201–400	102	194	66
401–600	131	249	81
601–800	73	275	91
801–1,000	41	312	92
1,001 and over	29	330	104

* A labor unit is 10 hours of man labor or 20 hours of horse labor.
† A day's labor is the average amount performed in a day of 10 hours. See Table IX.

On the farms where less than 200 units of labor were accomplished during the year, there were 107 days of productive work per man. This is less than one third as much as was accomplished on the farms which had more than 1,000 units of productive labor. The average per man on these farms was 330 days. Horses accomplished 46 days of productive work on the smallest farms or less than half as much as was accomplished by those on the largest farms.

The larger amount of work annually accomplished by horses on the larger farms was not obtained by a sacrifice in the number of colts raised (Table XXVI). In fact, more colts per farm and more colts per each ten horses kept were raised on the larger farms. The greater amount of work performed by the horses on the larger farms was not due to better horses, judging their ability to work by their appraised value. There was no decided variation from the average value of $141 for the various farm groups except in the group of farms comprising those of less than 40 acres. The average value of work horses for this group was $103.

TABLE XXVI
RELATION OF SIZE OF FARM TO VALUE, CROP ACRES, AND COLTS PER WORK HORSE, 400 FARMS

Size of farm	Crop acres per farm	Work horses per farm	Average value per work horse	Average colts per farm	Average colts per 10 work horses
Acres					
1–40	20	2.1	$103	0.3	1.3
41–80	45	3.0	131	0.6	2.0
81–120	71	3.7	137	0.9	2.3
121–160	99	4.5	146	1.0	2.2
161–200	121	5.6	142	1.4	2.5
201–240	152	5.9	146	1.4	2.3
241–280	161	6.6	147	1.4	2.1
281 and over	229	7.8	156	2.6	3.2
Average* or Total	89	4.3	$141	1.0	2.3

* Weighted averages, not averages of groups.

EFFECTIVE USE OF LABOR AND LABOR INCOME

In Tables XXVII and XXVIII and Figure 7 it will be noted that there was a constant rise in the average labor income as the amount of productive work accomplished per man and per horse increased. This is indicated especially where the relation between man labor and labor income is shown. On those farms where a man accomplished only 150 days or less of productive labor, the average labor income was only $31 per farm. The average labor income increased rapidly with an increase in the number of days of productive work accomplished per man. On those farms where the men averaged more than 350 days of productive labor per man, there was an average labor income of $637 per farm. The labor incomes did not increase so rapidly on the basis of the number of days of productive work accomplished per work horse as they did on the basis of the work accomplished per man. In other words, labor incomes did not appear to be influenced to the same degree by efficiency of horse labor as by efficiency of man labor. This is no doubt due to the fact that the cost of horse labor is approximately two thirds as much as the cost of man labor.[10] Work horses give additional returns in the production of colts, consequently their value to the farm business is not entirely dependent upon work performed.

TABLE XXVII
RELATION OF ANNUAL PRODUCTIVE DAYS OF MAN LABOR PER MAN TO LABOR INCOME, 395 FARMS*

Days of productive labor annually accomplished per man	Labor units per farm	Number of farms	Average labor income
150 and under	226	37	$31
151–200	390	74	178
201–250	534	102	205
251–300	590	92	456
301–350	800	56	551
351 and over	892	34	637

* A day's labor is the average amount of labor accomplished in a day of 10 hours. See Table IX.

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[10] Peck, F. W. The cost of producing Minnesota farm products 1908-1912; Field Crops. Minn. Agr. Exp. Sta. Bull. 145. 1915.

TABLE XXVIII

RELATION OF DAYS OF PRODUCTIVE LABOR ANNUALLY ACCOMPLISHED PER WORK HORSE TO LABOR INCOME, 395 FARMS*

Days of productive labor annually accomplished per work horse (Work horse units)	Labor units per farm	Number of farms	Average labor income
60 and under	373	74	$178
61–70	483	76	206
71–80	546	63	279
81–90	607	68	380
91–110	652	70	355
111 and over	786	44	490

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* A day's labor is the average amount of labor accomplished in a day of 10 hours. See Table IX.

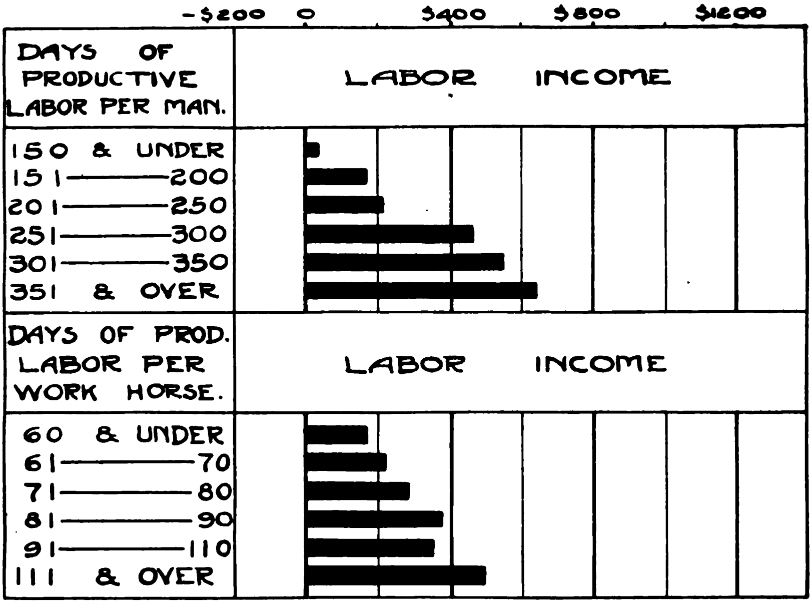

Fig. 7. Relation of Days of Horse and Man Labor Annually Accomplished per Horse and per Man to Labor Income

That the size of the labor income is closely related to the efficiency of man and horse labor is in full accord with facts already presented. The data in Table XXV show that the amount of labor accomplished per man and per work horse was twice as much on some farms as on others. The data in Table XXII show that the average cost of labor per farm is a very large item of expense. It follows that labor incomes will be higher on those farms where the labor expenses are low as a result of efficient use of labor. In general, horse and man labor were used more efficiently where the business was large (Tables XXVII and XXVIII). The average labor incomes of the farms grouped according to efficiency of labor were therefore also grouped, to a large extent, according to size of business. It has already been shown that size of business is an important factor in obtaining a satisfactory labor income.

DIVERSITY

Investigators of the United States Department of Agriculture and several of the state experiment stations have concluded that diversified farms, that is, farms which derive their income from two to four different sources, are more profitable than those which receive almost all of their income from one source.[11] Each crop raised for sale and each kind of productive livestock kept is usually considered a separate source of income.

ADVANTAGES OF DIVERSITY

A well-diversified farm business has three distinct advantages. (1) It enables the farmer to utilize cheap feeds such as pasture, cornstalks, and straw by means of livestock. Livestock is therefore an essential factor in the diversification of most farms. (2) It enables the farmer to make more effective use of the man and horse labor employed. The labor can be more evenly distributed throughout the year, and a larger proportion can be used productively. (3) It diminishes the risks. Where several enterprises are carried on, low prices, failure of one crop, or losses in one class of livestock, will not necessarily wipe out all profits as would be the case if all depended on the income from one enterprise and it should fail.

PERCENTAGE OF PRODUCTIVE LABOR INCREASED

Data from several farms in Minnesota for a period of ten years, show that on a large grain farm with practically no diversity, 58.4 per cent of the labor was employed on productive enterprises; on farms with little diversity, 67.5 per cent of the labor was productive; on farms with a still larger degree of diversity, 69.6 per cent was productive; and on farms well diversified, 73.6 per cent was productive. On the well-diversified farms, 15 per cent more of the labor was used in productive work than on the one undiversified farm mentioned.[12]

PERCENTAGE OF RECEIPTS FROM CROPS AS MEASURE OF DIVERSITY

The degree of diversity under some conditions is indicated by the percentage of receipts from the sale of crops. A large percentage of the total farm receipts from crop sales indicates that little or no productive livestock was kept. Any diversity is in the character of the crops raised. A small percentage of the total receipts from crop sales indicates that nearly all the crops raised were fed. The percentage of farm receipts from crop sales is a good indication of diversity only in years of approximately normal yields and prices. If there are low crop yields or low prices for crops and normal prices for livestock, the percentage of crop sales will likely be low. On the other hand, unusually high yields or high prices will result in a large percentage of receipts from cash crops. Under any one of the conditions mentioned, the actual diversity might be the same, because the acreage and kind of crop as well as the amount and kind of livestock might have been the same.

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[11] Spillman, W. J., Dixon, H. M., and Billings, G. A. Farm management practice of Chester County, Pa. U. S. Dept. of Agr. Bull. 341. p. 82. 1916.
Johnson, O. R., Successful farm organization. Mo. Agr. Exp. Sta. Bull. 142. p. 17. 1916.
Warren, G. F. Some important factors for success in general farming and in dairy farming. Cornell Univ. Agr. Exp. Sta. Bull. 349. p. 693. 1914.

[12] Cooper, T. P., Peck, F. W., and Boss, Andrew. Labor requirements of crop production. Minn. Agr. Exp. Sta. Bull. 157. p. 20. 1916.

The labor incomes in the Rice County survey did not show any decided change with the variations in percentage of receipts from crops sold where less than 50 per cent of the income was obtained from that source (Table XXIX and Figure 8). It will be noted that only thirty-six of the farms, or less than one in ten, received more than 50 per cent of the receipts from crops. The average labor income of these farms was $178 as compared with $319 for all farms. This is strong evidence that the nine tenths of the farmers in this locality who made stock-raising and dairying leading enterprises were wise. Each farmer should put his labor and capital into those enterprises which will be most profitable for him through a series of years.

TABLE XXIX

RELATION OF PERCENTAGE OF FARM RECEIPTS FROM SALES OF CROPS TO LABOR INCOME

Percentage of receipts from sales of crops	Number of farms	Average labor income
10 and under	58	$300
11–20	84	330
21–30	93	404
31–40	81	247
41–50	48	316
51 and over	36	178
Average* or Total	400	$319

* Weighted averages, not averages of groups.

LIVESTOCK AND DIVERSITY

Since livestock is an essential factor in diversification, the intensity with which a farm is stocked is an indication of the degree of diversification. The number of acres per animal unit is a measure of this intensity. The relation between the number of acres per animal unit and the labor income is shown in Table XXX and Figure 8. Farms with a small number of acres per unit of productive livestock were intensively stocked, while those with a large number of acres for each unit were lightly stocked. On the heavily stocked farms most of the crops were fed, while on the lightly stocked farms most of the crops were sold. It follows that the intensity with which a farm is stocked is an indication of the relative amount of income from sales of crops, and from livestock or livestock products. The size of labor incomes, Table XXX, indicates that those farms with one animal unit to each five or six acres were the most profitably diversified.

TABLE XXX

Relation of Acres per Unit of Productive Livestock to Crop Index, Animal Index, and Labor Income*

Acres per animal unit	Number of farms	Crop index	Animal index	Average labor income
4.0 and under	18	109	103	$423
4.0–5.0	30	114	100	434
5.1–6.0	63	106	97	486
6.1–7.0	65	104	104	374
7.1–8.0	52	99	99	292
8.1–9.0	53	96	101	244
9.1–10.0	35	95	97	109
10.1–15.0	51	95	92	225
15.0 and over	28	86	93	29

* Average crop and animal indexes are not weighted averages but are obtained by using each farm as a unit.

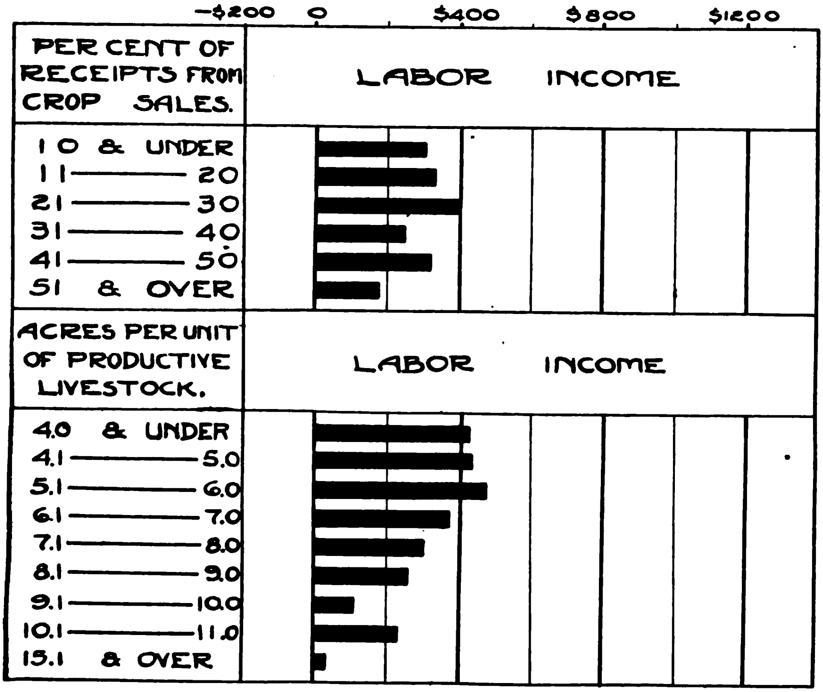

Fig. 8. Relation of Percentage of Receipts From Crops and Acres per Unit of Productive Livestock to Labor Income

Where there were less than 5 acres per animal unit, the farm was tending toward specialization in livestock rather than diversification, and the benefits derived from the livestock as a factor in profitable diversification were reduced. As farms become intensively stocked a larger amount of high-priced feeds is used, extra labor is required, especially at some periods, and greater risks are incurred. As a result, the average labor income decreased to a slight extent where there were less than 5 acres for each unit of productive livestock. It is well to note, however, that with highly productive livestock, heavy stocking is often the most profitable course to pursue regardless of its effect on diversity.

DIVERSITY FOR INDIVIDUAL FARMERS

Many of the most successful farmers have several major enterprises in the farm business. The proper diversity for any farmer is that arrangement of his farm business which will give him the greatest profits through a series of years. It means a business that will insure him a reasonably steady income and such a system of farming as will maintain the producing power of his soil. Under special market conditions, an occasional farmer makes satisfactory profits by specializing on one crop or class of livestock.

FIVE IMPORTANT FACTORS IN DETERMINING FARM PROFITS

The data presented in preceding tables show that under the conditions existing in Rice County when the survey was taken there were several factors which in a large measure determined the financial success of a farm business. These factors were (1) the size of the returns per unit of productive livestock; (2) the size of farm business as measured by the total amount of productive work accomplished by men and horses; (3) the crop yields per acre; (4) the amount of labor accomplished annually per man, and (5) the amount of labor accomplished annually per work horse. The effect of these factors on labor income is shown in Figures 9 and 10.

In actual practice there is always more than one factor influencing the size of the labor income either directly or through some interrelation. The effect of the receipts per unit of livestock on labor income is closely linked with the amount of livestock kept in proportion to the acreage. Crop yields are often very greatly influenced by the amount of livestock kept and the amount of manure applied to the land. The size of business is very greatly affected by the character of the crops grown and by the kind and amount of livestock raised. The farms having the largest farm business in turn afford the best opportunity for the most profitable use of man and horse labor.

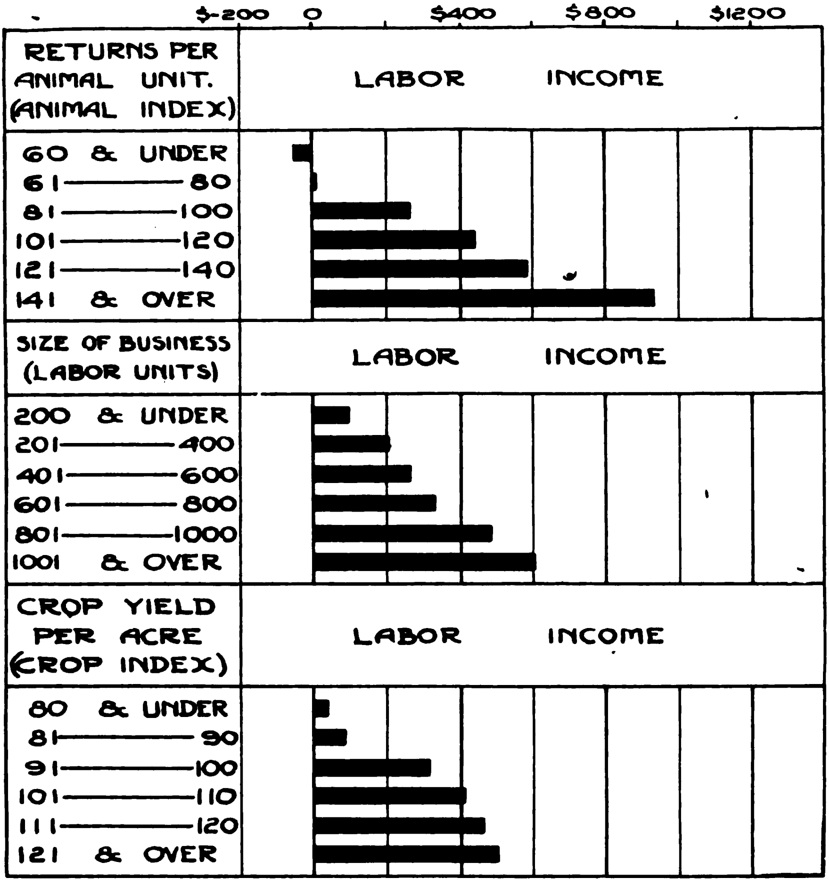

Fig. 9. Summary of Relation of Important Efficiency Factors to Labor Income.

It is desirable to segregate if possible the effect on labor income of each of the factors just discussed. In the Rice County survey the labor incomes increased more uniformly and consistently with an increase in the average returns per unit of productive livestock than with any other factor. This factor is expressed in terms of animal index. Since no other single factor seems to have influenced the size of labor incomes to the same extent, the returns per unit of productive livestock have been combined with other important factors in order to determine what effect these other factors had on labor incomes regardless of the productivity of the livestock. This arrangement prevents the real effect of the less important factors from being covered up by the very great importance of the receipts per unit of productive livestock.

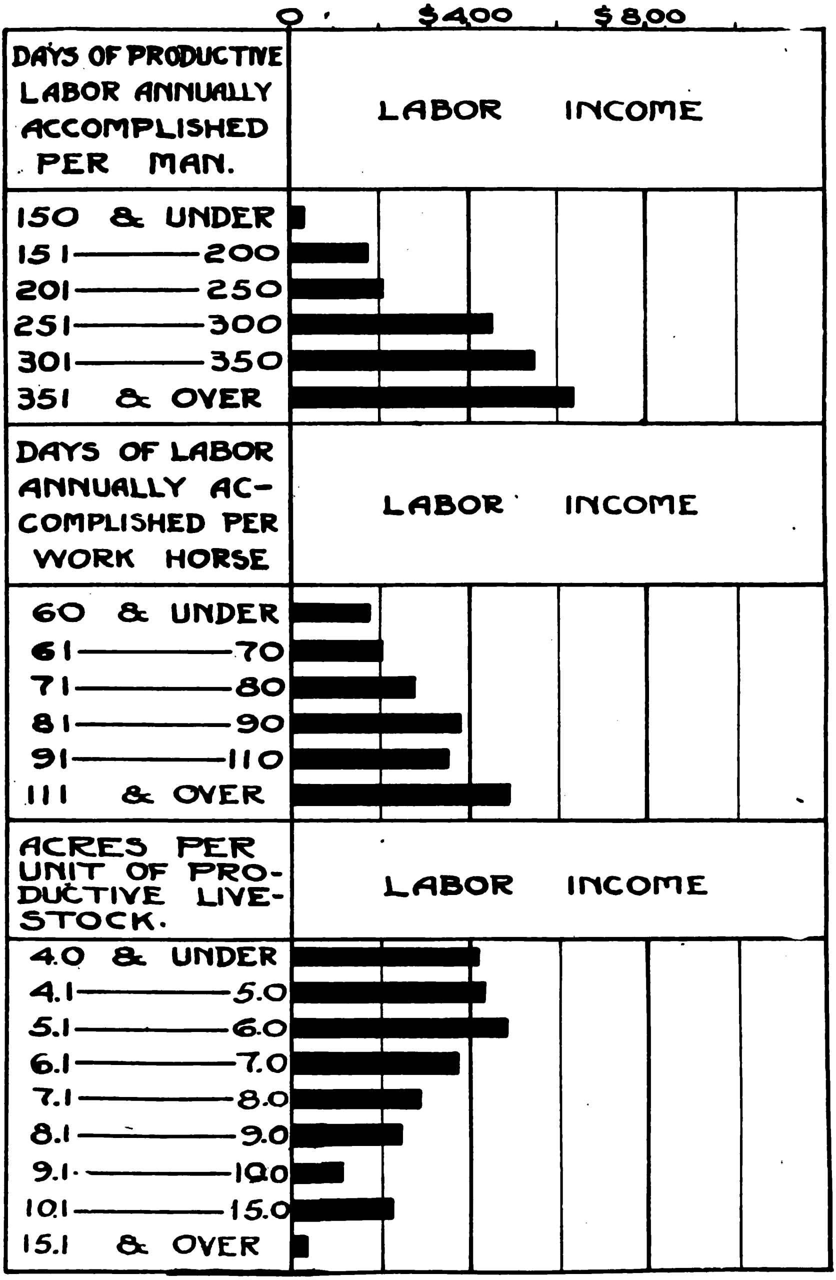

Fig. 10. Summary of Relation of Important Efficiency Factors to Labor Income.

SIZE OF BUSINESS AND PRODUCTIVITY OF LIVESTOCK

In Table XXXI and Figure 11 the effect on labor incomes of the returns per unit of productive livestock and the size of business is shown. From previous tables it is evident that the average size of the labor incomes when classified into groups according to animal index will increase as animal index increases. If labor incomes always increased as the size of business increased, regardless of the production per unit of livestock, there would have been a constant increase in the size of labor incomes in each animal index group, but this was not the case. In the first and second groups, where the returns per unit of livestock were very low, there was, with one exception, a decrease in the labor income as the size of the business increased. The decrease in labor income followed because practically all of the farms with a large business kept considerable livestock, and when the stock was of low production the returns from the labor and feed used were also low. In the third group the livestock was not quite so productive as the average, but there was little variation in the size of labor incomes as the size of the business increased. The depressing effect of increasing amounts of livestock of medium production, was counteracted by the increasing size of business. In the

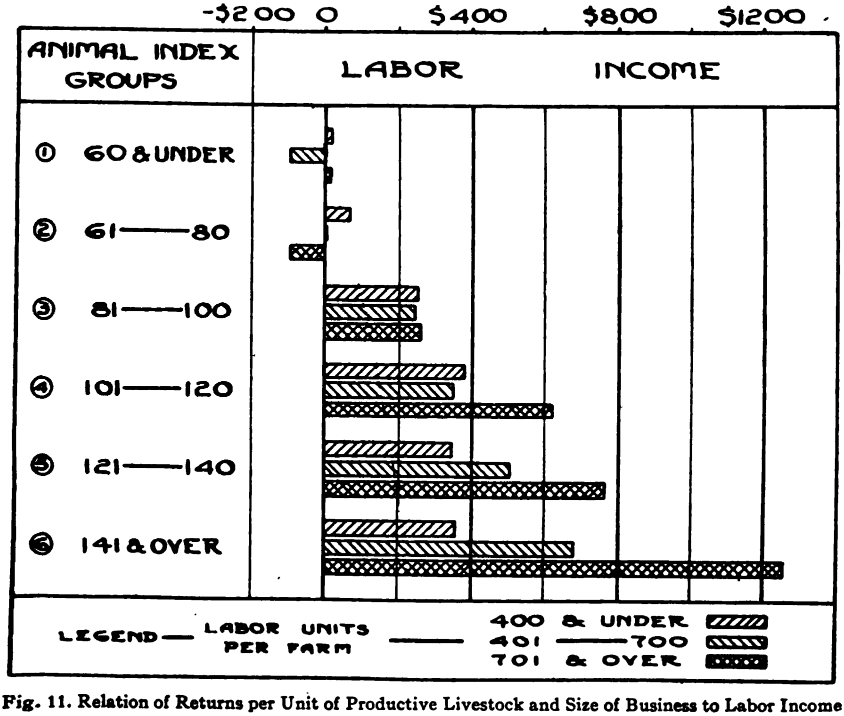

Fig. 11. Relation of Returns per Unit of Productive Livestock and Size of Business to Labor Income

fifth and sixth groups, the livestock was better than the average, and the average labor income consistently increased as the size of business increased.

TABLE XXXI

Relation of Animal Index and Labor Units to Labor Income, 395 Farms

Animal index group*	Labor units per farm					
	400 and under		401–700		701 and over	
	Number of farms	Labor income	Number of farms	Labor income	Number of farms	Labor income
60 and under	22	$18	16	$-96	5	$14
61–80	32	71	40	6	17	-92
81–100	28	256	49	245	25	265
101–120	13	383	34	351	19	623
121–140	13	349	20	507	18	769
140 and over	11	359	17	684	16	1,254

* One hundred equals the average of the area.

OPERATING CAPITAL AND PRODUCTIVITY OF LIVESTOCK

The effect on labor income of returns per unit of productive livestock (animal index) and amount of operating capital is shown in Table XXXII and Figure 12. The first and second groups show a decrease from a small plus labor income to a minus labor income as the amount of operating capital increased. In the third group, where the livestock was fairly productive, the labor income did not change to any extent as the amount of operating capital increased. The profits from a larger business counteracted the depressing influence of the rather unproductive livestock. In the fourth, fifth, and sixth groups the size of the labor income was very favorably influenced by increasing the amount of operating capital.

TABLE XXXII

Relation of Animal Index and Operating Capital to Farm Income, 395 Farms

Animal index*	Operating capital					
	$2,000 and under		$2,001–$3,000		Over $3,000	
	Number of farms	Labor income	Number of farms	Labor income	Number of farms	Labor income
60 and under	34	$11	4	$-24	5	$-270
61–80	53	61	21	-53	15	-77
81–100	46	286	29	211	27	241
101–120	21	344	27	418	18	576
121–140	16	402	14	551	21	687
141 and over	11	502	18	627	15	1,257

* One hundred equals the average of the area.

The conclusion to be drawn is that where the productivity of the livestock was less than 80 per cent of the average, the labor incomes were reduced as the amount of operating capital increased.

Where the livestock was from 80 to 100 per cent as productive as the average, the labor incomes were not influenced by the amount of the operating capital. Where the livestock was more productive than the average, the labor incomes were increased as the amount of operating capital increased.

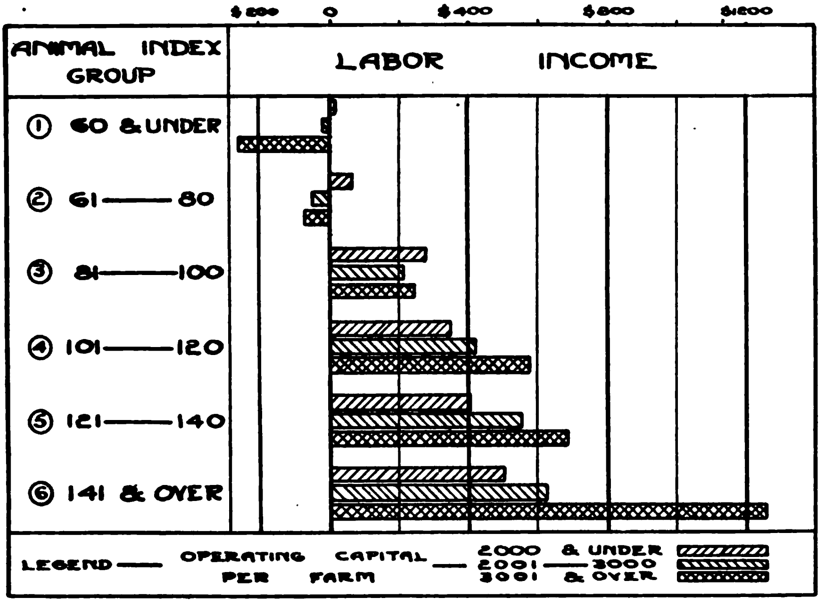

Fig. 12. Relation of Returns per Unit of Productive Livestock and Operating Capital to Labor Income

CROP YIELDS AND PRODUCTIVITY OF LIVESTOCK

The average size of crop yields had a direct influence on the size of the labor income (Table XXXIII and Figure 13). In all but one of the divisions of the animal index groups there was an increase in the labor income as the size of the crop yields increased. The increase in the labor income due to increasing crop yields was not nearly so great as that due to increase in productivity of livestock.

TABLE XXXIII
RELATION OF ANIMAL INDEX AND CROP INDEX TO LABOR INCOME, 395 FARMS

Animal index groups*	Crop index*					
	90 and under		91–110		111 and over	
	Number of farms	Labor income	Number of farms	Labor income	Number of farms	Labor income
60 and under	20	$-152	11	$136	12	$40
61–80	39	-91	36	68	14	145
81–100	22	65	48	231	32	415
101–120	16	166	30	449	20	638
121–140	6	528	27	540	18	601
141 and over	4	509	25	749	15	993

* One hundred per cent equals the average of the area.

An extra amount of labor and expense on crops already giving good yields does not bring so much profit as the same amount of extra labor and expense on productive livestock. In the area surveyed there were 28 farms showing a labor income of $900 or more. Of these, 10, or 35.7 per cent, were below the average in crop index, while only one was below the average in animal index.

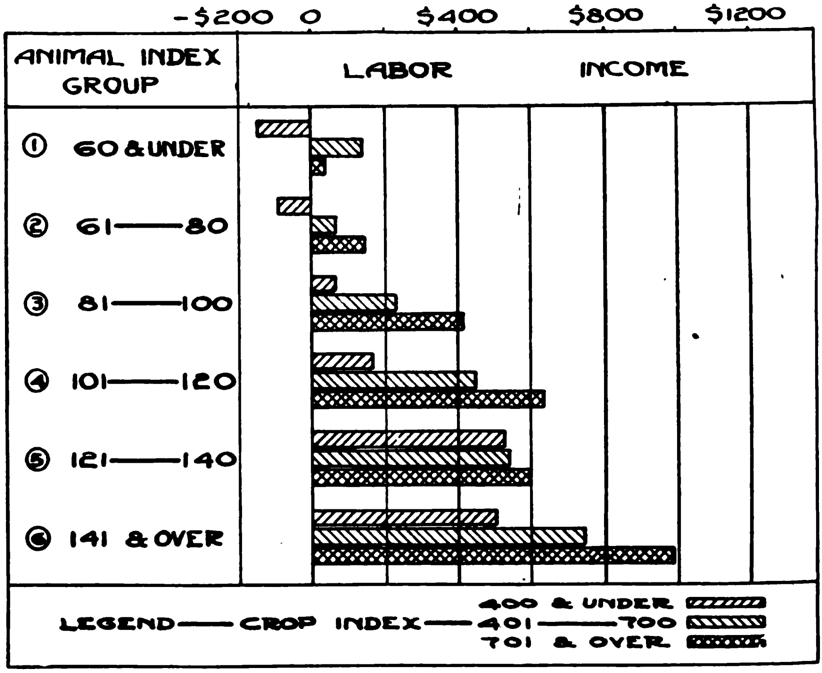

Fig. 13. Relation of Returns per Unit of Productive Livestock and Crop Yields per Acre to Labo Income

MAN LABOR AND PRODUCTIVITY OF LIVESTOCK

The combined effect on labor income of the returns per unit of productive livestock and efficiency of man labor is shown in Table XXXIV and Figure 14. The labor incomes returned by the farms having the highest man labor efficiency indicate that it was possible for farmers to obtain labor incomes of fair size even when handicapped by livestock of low production. In the animal index groups where the livestock was at least 80 per cent as productive as the average, the labor incomes constantly increased as the efficiency of man labor increased.

TABLE XXXIV

RELATION OF ANIMAL INDEX AND DAYS OF PRODUCTIVE LABOR ANNUALLY PER MAN TO LABOR INCOME, 395 FARMS*

Animal index groups†	Days of productive labor per man					
	200 and under		201–300		301 and over	
	Number of farms	Labor income	Number of farms	Labor income	Number of farms	Labor income
60 and under	18	$18	19	$–103	6	$91
61–80	26	65	45	–39	18	155
81–100	31	25	47	292	24	470
101–120	13	197	36	408	17	684
121–140	12	366	25	546	14	742
141 and over	12	396	20	743	12	1,336

* A day's labor is considered the average amount accomplished in a day of 10 hours. See Table IX.

† One hundred equals the average of the area.

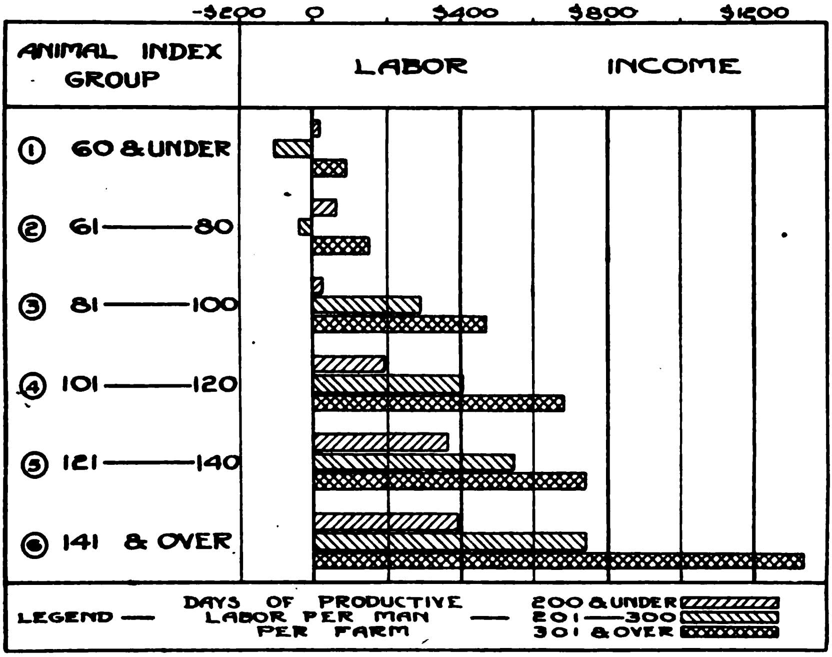

Fig. 14. Relation of Returns per Unit of Productive Livestock and Days of Productive Labor Annually Accomplished per Man to Labor Income

HORSE LABOR AND PRODUCTIVITY OF LIVESTOCK

In Table XXXV and Figure 15, the farms were again grouped according to the average size of the returns per unit of productive livestock and the relation shown between horse labor efficiency and labor incomes. In general, the labor incomes increased but the effect of horse labor efficiency on labor incomes was not so great as that of man labor efficiency.

TABLE XXXV

Relation of Animal Index and Days of Productive Labor Annually per Work Horse to Labor Income*

Animal index groups†	Days of productive labor per work horse					
	70 and under		70–90		91 and over	
	Number of farms	Labor income	Number of farms	Labor income	Number of farms	Labor income
60 and under	19	$-78	11	$-64	13	$78
61–80	34	18	34	56	21	-74
81–100	47	205	30	304	25	283
101–120	23	347	20	423	23	540
121–140	16	426	19	501	16	764
141 and over	11	478	17	895	16	949

* A day's labor is considered the average amount accomplished in a day of ten hours. See Table IX.

† One hundred is the average of the area.

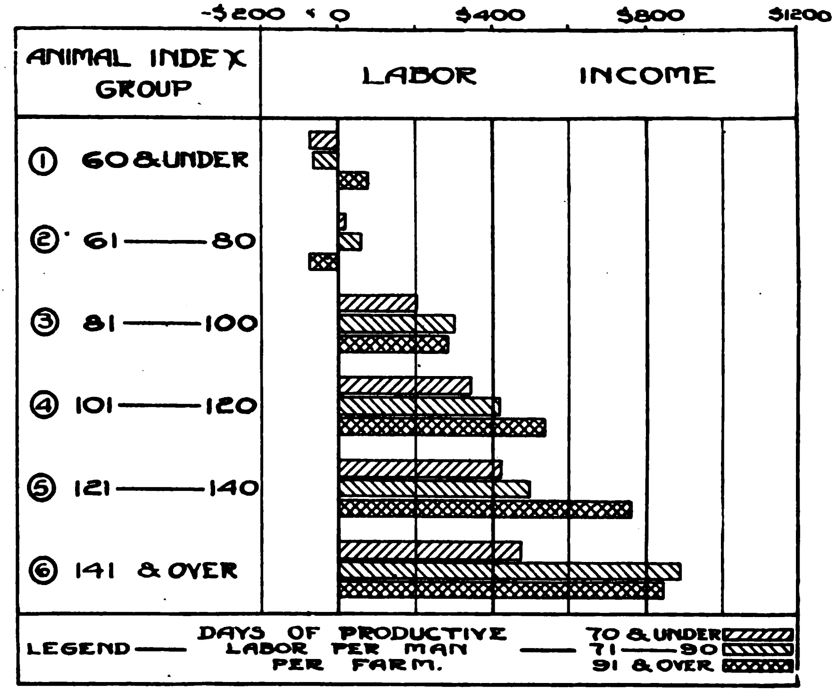

Fig. 15. Relation of Returns per Unit of Productive Livestock and Days of Labor Annually Accomplished per Work Horse to Labor Income

RELATION OF FARM BUSINESS EFFICIENCY FACTORS TO LABOR INCOME

That the five factors, namely, size of business, size of returns per unit of productive livestock, average crop yields per acre, efficiency of man labor, and efficiency of horse labor, are very important in the area studied is evident from the data shown in Table XXXVI. The more of these factors per farm equal to or above the average, the larger was the labor income. There were 26 farms which had all the efficiency factors equal to or above the average. Of these, all but one returned a labor income of $400 or more, and 11, or 42.3 per cent, returned labor incomes of $1,000 or more. Under the farming conditions which existed in the area studied, it is evident that a farm with the five efficiency factors as good as the average or better was practically certain to return a labor income of more than average size. Nearly half of the farmers who met these conditions made labor incomes of $1,000 or more.

TABLE XXXVI

RELATION OF FARM BUSINESS EFFICIENCY TO LABOR INCOME, 395 FARMS*

	All farms		Farms with labor incomes of $400 and over		Farms with labor incomes of $1,000 and over	
	Number of farms	Labor income	Number of farms	Percentage of group	Number of farms	Percentage of group
Above the average in *none* of the factors......	47	$-10	2	4.3	0	0
Above the average in any *one* of the factors...	85	51	10	11.7	0	0
Above the average in any *two* of the factors...	82	235	29	35.4	0	0
Above the average in any *three* of the factors..	93	323	40	43.0	1	1.1
Above the average in any *four* of the factors...	62	649	44	70.8	11	17.7
Above the average in all *five* of the factors....	26	947	25	96.1	11	42.3

* Five efficiency factors are considered and the farms are grouped according to the number of these factors in which they excel the average. The factors are: (1) Size of business, (2) returns per unit of productive livestock, (3) crop yields per acre, (4) number of days of productive labor annually accomplished per man, (5) number of days of productive labor annually accomplished per horse. A day's labor is considered the average amount accomplished in a day of 10 hours. See Table IX.

FARM MANAGEMENT PRINCIPLES AS APPLIED TO TWO INDIVIDUAL FARMS

In order to show in a concrete way how farm management principles may be used in analyzing an individual farm business, data from two farms are given in Tables XXXVII, XXXVIII, and XXXIX. It is not primarily intended that the farms be compared with each other, but rather that an opportunity be given to study the business of two successful farms of different sizes. Farm A was one of the most profitable 80-acre general farms so far recorded by the Minnesota Experiment Station. The labor income was $1,573. Farm B was a very successful 200-acre farm which returned a labor income of $2,484. It will be noted in Table XXXVII that the investment in Farm A was $12,204 and that $3,404, or 27.9 per cent, was operating capital. The investment in Farm B was $26,440 of which $6,440, or 24.3 per cent, was operating capital. On both farms the major part of the operating capital was invested in livestock.

TABLE XXXVII

Investment	Farm A 80 acres	Farm B 200 acres
Real estate	$8,800	$20,000
Machinery	378	676
Livestock	2,396	5,194
Grains and feeds	630	570
Total	$12,204	$26,440

SOME DETAILS OF THE BUSINESS

The business of Farms A and B is shown in considerable detail in Table XXXVIII. A four-year rotation consisting of: first year, corn; second year, corn and small grain, one half of the field in each crop; third year, small grain seeded to clover and timothy; and fourth year, clover and timothy hay, was followed on Farm A. On Farm B a five-year rotation was used consisting of one year of corn, three years of small grain, and one year of clover and timothy hay.

TABLE XXXVIII
Some Details of the Business

Use of land	Farm A, 80 acres			Farm B, 200 acres		
	Acres	Yield per acre	Financial summary	Acres	Yield per acre	Financial summary
Corn grain	14	51 bu.	$130	17	41 bu.	
Corn silage	7	10 tons		15	10 tons	
Wheat	11	20 bu.	165	15	10 bu.	$102
Oats	10	61 bu.	47	33	47 bu.	162
Barley				35	25 bu.	354
Flax				9	15 bu.	181
Hay (clover and timothy)	15	1½ tons	68	30	2 tons	83
Pasture	19			35		
Farmstead, woods, and waste	4			11		
Livestock	Number kept			Number kept		
Cows	12		$168	23		$80
Young cattle	11		286	14		965
Horses	4			7		
Colts				2		150
Swine	5 sows		693	8 sows		857
Poultry	75		11	150		12
Livestock products	Amount			Amount		
Cream	3,107 lbs. butterfat		$932	2,200 gal.		$792
Milk				93,000 lbs.		1,150
Eggs				412		75
Increase in machinery						258
Miscellaneous						61
Total receipts*			$2,500			$5,282
Expenses						
Labor	$84			$433		
Feed and seed	85			370		
New machinery	33			293		
Machinery and building repairs	14			105		
Twine, threshing, and silo filling	47			147		
Taxes and insurance	42			90		
Miscellaneous	12			38		
Total expense			$317			$1,476
Farm income			$2,183			$3,806
Interest on investment at 5 per cent			610			1,322
Labor income			1,573			2,484

* Receipts include sales plus any increase in inventory or minus any decrease.

The major sources of income were cattle, dairy products, swine, and grain. On the 80-acre farm little extra feed was purchased or extra labor used, and the expenses were very low. The expenses on Farm B were higher, but not too high considering the size of the business.

TABLE XXXIX
EFFICIENCY FACTORS COMPARED WITH THE AVERAGE

Factors	Average for the farms studied	Farm A 80 acres	Farm B 200 acres
Labor units per farm	555	473	1,007
Returns per unit of productive livestock	100 per cent	50 per cent above average	100 per cent above average
Sales of dairy products per cow	$46	$78	$85
Average crop yields per acre	100 per cent	33⅓ per cent above average	Average
Man labor efficiency	249 days per year*	20 per cent above average	50 per cent above average
Horse labor efficiency	81 days per year†	15 per cent below average	Average
Acres of land for each unit of productive livestock	7.8	3.4	5.6

* A day of man labor is the average amount of labor accomplished by a man in a day of 10 hours. See Table IX.

† A day of horse labor is the average amount of labor accomplished by a horse in a day of 10 hours.

EFFICIENCY FACTORS COMPARED WITH THE AVERAGE

In Table XXXIX Farms A and B are compared with the average of the 400 farms in the survey with regard to some of the important factors of a farm business. The 80-acre farm, A, with 37.5 per cent of the crop area in cultivated crops, and with 3.4 acres of land for each unit of productive livestock, was intensively operated, nevertheless only 473 units of productive labor were accomplished. The 200-acre farm, B, with 20.5 per cent of the crop area in cultivated crops and 5.6 acres of land for each unit of productive livestock, was not nearly so intensively operated, but 1,007 units of productive labor were accomplished. This was due to the much larger business that the larger farm made possible. Both farms were above the average in productivity of livestock, in crop yields per acre, and in efficiency of labor except in the case of horse labor on the smaller farm. A small farm usually has difficulty in using labor effectively. Some purebred dairy stock was kept on the 200-acre farm, and the returns per unit of livestock were higher than on the 80-acre farm. The crop yields were lower on the larger farm. On both farms the returns per unit of livestock and crop yields per acre were much larger than the average. The chief point of difference was in the size of business. Both farms returned large labor incomes, and had a systematically planned farm business embodying the principles of profitable farm management.

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BULLETIN 173 FEBRUARY 1918

The University of Minnesota

AGRICULTURAL EXPERIMENT STATION

THE COST OF MILK PRODUCTION

PART I. FACTORS OF COST

PART II. APPLICATION OF THE FACTORS IN DETERMINING THE COST OF MILK AT NORTHFIELD, HALSTAD, AND COKATO

BY

F. W. PECK AND ANDREW BOSS

DIVISION OF AGRONOMY AND FARM MANAGEMENT

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THE COST OF MILK PRODUCTION

By F. W. PECK and ANDREW BOSS

INTRODUCTION

Milk is recognized as an indispensable human food. No substitute has ever been found for it. It is especially valuable as a food for infants and growing children. It is also a highly desirable food for adults and is regarded as one of the necessities to human comfort and health. Milk is one of the most important agricultural products and its production must be fostered sufficiently to insure an abundant and healthful supply.

Dairying is looked upon as one of the most profitable types of farming. Dairy farms are usually productive and many of them are well managed. Business men, bankers, and farmers as well report that dairying in the past has usually been associated with well-to-do farmers and a prosperous community. But the stability of the dairy business seems to be threatened. Dairymen the country over complain that they are producing milk at a loss. Such investigations as have been made indicate that both milk and butterfat have been sold below the cost of production and certainly at less than their value in comparison with other food products. Many of the producers of milk have threatened to sell their cows and go out of the business. Some of them have already done so. Milk strikes have become frequent and sometimes serious. Some of the dairymen are ceasing to raise their dairy calves and this is always an indication that the business is waning. The apparent past prosperity of the average dairy farmers, it is explained, has been only apparent and not real. With their milk they have been marketing a part of the fertility of their soil for which they have received no compensation. They have produced cheap milk by charging little or nothing for the labor of their families which has been freely used in the production of both crops and milk. Now that land is becoming scarce and high priced, attention must be given to rebuilding and maintaining the fertility of the soil. The competition of the industries and the war for farm labor is forcing recognition of the fact that the labor of the farmers' sons and daughters is a legitimate part of the cost of production and that it must be paid for on the same basis as labor in the other industries. Dairying can no longer be successfully conducted on the *partial payment* plan. It must be reorganized on a *full payment* basis. Milk cannot be produced economically in cities. Therefore people who live in cities must pay those who live in the country for producing their milk supply. The consumers of milk and butterfat will have to pay enough for the product to enable the producers to stay in the business, or they themselves will have to become producers. It is wise to pay enough for milk that enough producers will stay in the business to prevent the price of milk from rising still higher.

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Cokato (Wright County).—L. L. Wanha, Matt Hasti, O. Nyquist, O. A. Holmer, Otto Munson & Bro., J. A. Hoagland, Emil Ek, John Tapio, A. F. Stein, Albert Titrud, Gus Strolberg, and Alex Onkka.

THE COST OF MILK

Prices for milk have been fixed in many cities but not satisfactorily fixed. The questions keep coming back: What is a fair price for milk? What does it cost to produce milk? Should milk be sold for its cost or at its value as a food? and others. Few who ask the questions realize how dependent the human race is on the milk supply. A less number have any idea how complicated the problem of determining a fair price for milk really is. Obviously the cost of any product depends on the commodities entering into it, the value of these commodities, and the efficiency of manufacture. But the price that should be paid for a product or commodity depends on how much the product is needed or desired. Sometimes the price is above cost, sometimes far below. When it is too far below cost a readjustment of values must be made and that is what is now occurring in the dairy business. In making the readjustment a study of cost is essential to a thoro understanding of the problem, even tho it may not be the base from which the price ultimately is determined. A study of costs enables the operator to control the different factors of cost in order to secure efficiency of production. An accurate statement of costs will enable the dairyman to study his business and develop methods by which milk or butterfat can be produced most cheaply. It will also serve as one of the factors which determine whether or not he can afford to stay in the business, but it does not necessarily determine the price for which milk should be sold. Values also must be considered. Values rather than cost may well be the determining factor in fixing the price.

Another function of a standardized and accurate system of learning the cost of producing milk would be to satisfy the consumer that it is *cost plus a reasonable profit,* and not *exorbitant profits,* that he is paying in the increased price of milk. Such a system would permit also of a comparison of costs between different sections of the country and would eventually be useful in bringing producers and consumers together in an understanding of what is a fair price for milk.

SOURCES OF DATA

Part I is a discussion of the various factors that enter into the cost of producing milk. The data presented partake of the nature of engineering data in that the bases for computing the various costs rather than any set figures of cost are discussed. This discussion is essential to the clear interpretation of the data as presented in Part II and to an understanding of the cost of producing milk. The records from three statistical routes of Minnesota farms furnish the basis for the publication.

Table I shows important facts concerning the investigation.

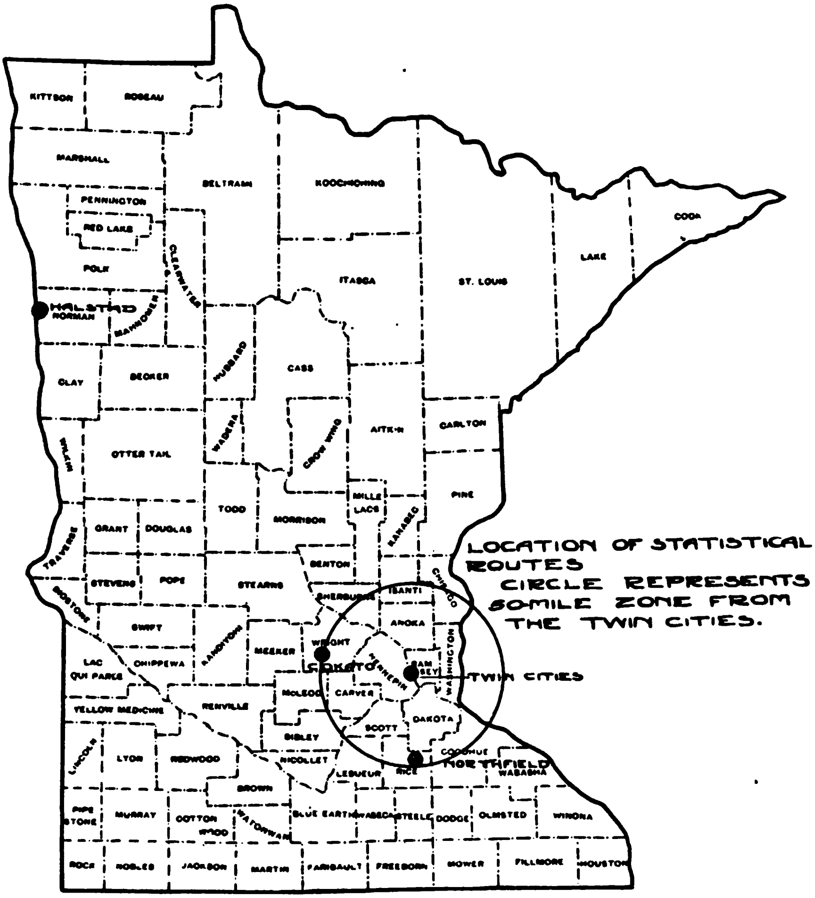
TABLE I

Location of route	Av. No. farms	Years covered	No. years	Total No. cows	Av. No. cows annually	Av. No. cows per herd
Northfield, Rice County	6	1908-1912	5	473	94	15
Halstad, Norman County......	7	1912-1916	5	330	66	10
Cokato, Wright County......	8	1913-1916	4	501	125	15

Practically all of the cows in this study in each of the localities were grade cows. Holstein breeding predominated at Northfield, Guernsey and Shorthorn breeding were more prominent at Halstad and Cokato. The values of these cows during the years when the data were obtained were low as compared to present values. An average value per cow of $50 to $60 at that time would be comparable with $80 to $90 now as indicating the productive value of the cow.

DATA PRESENTED

In presenting these data the aim has been to set out plainly the kinds and amounts of the various commodities entering into the production of milk. With these determined, it is possible to calculate quite closely the cost of producing milk for any locality under stated conditions and prices. The application of the data to the problem is shown in Part II. The data are offered, not to settle permanently the price of milk, but to show how the cost of milk may be determined.



PART I

FACTORS OF COST

THE COW

Cow cost is made up of interest on a fair inventory value, taxes, insurance, and depreciation. Young cattle are not included in the presentation of these data, heifers being classed as cows when freshening. Interest is usually charged at the rate of 6 per cent of the inventory value. Taxes and insurance as costs were calculated by using the current rates. For the cows concerned, the tax rate is approximately 0.5 per cent on a two-thirds valuation of the herds. The insurance rate varies with the locality and the season, as most of the insurance carried is with farmers' mutual insurance companies. The average cost per cow for taxes and insurance for the years considered in this study amounted to 40 cents at Northfield, 28 cents at Halstad, and 35 cents at Cokato.

Depreciation of the cow is one of the points on which authorities differ. The basis for depreciating values in cows is the milking life of the cow. Considering merely one or two years and the buying and selling of cows rather than the steady production of milk for a term of years gives the basis for appreciation of values. During the last year, for instance, there has been a keen demand for good cows, market prices have risen, and all cows have increased in sale price. Normally, however, cows grow less valuable with age as producers, even on a market basis, and depreciation is a proper charge to make in the business of producing milk. Speculators may not experience much depreciation but farmers usually do. If the young heifers are included in the cow enterprise and not separated in the records of cost, it may be claimed that the young grow up and replace the old and, therefore, there is no depreciation. This is only confusing the point. Young cattle should pay for their keep in increased value to the farm. The individual cow is the unit with which the farmer is concerned.

Depreciation should cover two factors of loss, death risk or loss and decreased value in production of milk. On the herds studied the death loss amounts to 1.5 per cent of the value of the cows in the herds. An average milking life of six years has been assumed, altho it is known that many cows do not remain in milking herds so long.[1] After six years of milking, the cow is usually sold for beef and hence has a market value for the block. The formulas for determining depreciation would appear thus:

Depreciation=(1.5% of inventory value) + 16⅔% of (inventory value—block value).

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[1] Larson, C. W. Milk production cost accounts. Columbia University Press, 1916.

For example, a cow is valued at $100 as a producer and is worth $50 on the block. (1.5% of $100) + 16⅔% of ($100—$50)=$9.83, depreciation.

The total cow cost is the sum of the interest, taxes, insurance, and depreciation.

As an indication of the quality of cows in the various localities, Table II presents the production of milk and butterfat per cow by months and the total for the year.

TABLE II

MILK AND BUTTERFAT PRODUCED PER COW

Months	Northfield		Halstad		Cokato	
	5-year average		5-year average		4-year average	
	Milk	Butterfat	Milk	Butterfat	Milk	Butterfat
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
January	492	16.7	409	17.6	362	16.1
February	499	16.8	383	16.8	352	14.8
March	527	17.8	414	17.5	407	16.7
April	513	17.2	406	16.5	459	18.6
May	562	19.1	473	19.3	582	23.1
June	622	21.0	490	20.3	590	23.0
July	480	17.1	447	18.2	502	20.3
August	365	13.3	386	15.7	426	17.5
September	312	11.3	342	14.4	357	15.8
October	336	11.9	369	16.2	330	15.0
November	363	12.3	338	14.9	269	11.9
December	469	15.5	392	18.2	308	13.6
Totals	5,540	190.0	4,849	205.6	4,944	206.4

THE SIRE

Sires must be maintained in the dairy business, and the cost of providing and feeding them is a legitimate part of the cost of milk production. Most of the sires used in the herds studied were purebred. Holstein sires predominated in all localities, with Guernseys next and Shorthorns on a few of the farms. A valuation of $175 would be a close estimate of the sale value of the sires.

The sire cost is made up of interest on the inventory value, depreciation, feed, labor, shelter, equipment, taxes, insurance, and any general expense that may be incurred such as medicine, veterinary services, registration fees, and testing fees. A possible credit lies in obtaining service fees, but on most farms very little revenue is derived from this source. For the years concerned in this investigation and at the prices that obtained, the sire cost per cow amounted to $3 at Northfield, $4 at Halstad, and $3.60 at Cokato. Fewer cows per herd at Halstad, even tho the feed cost was lower, caused the higher cost per cow. As an average cost per cow for sire service, $4 is believed to be a fairly close estimate at the present time.

FEED

Feed is the largest single factor of cost in dairying and usually is greater than all other cost factors combined. This factor, more than any other, determines the possibility for the economic production of milk. With price and quality of feed the dominant considerations, there remains the problem of combining them into a balanced ration. Herein lies the science of dairy production. Probably the gravest mistakes of the business exist in this single problem.

The important point in a study of this kind is the amount of the various kinds of feed consumed per cow by months. When the feed consumed per month is compared with the production of milk by months one of the large factors in seasonal costs is readily understood. Knowing the amount of feed consumed, one may apply any current price and thereby closely approximate the feed cost. A knowledge of what proportion the feed cost is of the total cost, by months, affords the means of quite accurately and easily determining the cost of producing milk.

Tables III, IV, and V present the amounts of feed consumed per cow per month in the three localities.

Farm-grown grains constituted 62 per cent of the grain fed to the cows at Northfield; 91 per cent at Halstad; and 82 per cent at Cokato. Bran was the principal commercial feed, averaging 76 per cent of all purchased feed. Corn silage was fed to most of the cows on record at Northfield, but to only three herds at Halstad, and two at Cokato. For this reason the silage consumed at Halstad and Cokato may be included with the roughage. Three pounds of silage is regarded as equivalent to one pound of hay.

Pasture constitutes an important part of the annual feed of the cow on Minnesota farms. Making an accurate pasture charge is not always an easy task. Where second crop hay, corn fields, and stubble fields containing clover are used as pasture for cows, good judgment must be used in making the pasture charge. Pasture used only for cows may be charged on the basis of 6 per cent of the acre valuation of the land and an estimate of the number of acres used per cow. On Minnesota farms it is found that two acres is a close estimate of the pasture required per cow for the season of approximately five and one half months. Some barn feed will also be consumed in this time as is evident from a glance at Tables III, IV, and V. This makes a pasture cost of about $12 per cow. Where a monthly charge seems best on temporary pasture a charge of $1.50 to $2 per cow per month is a fair estimate, depending on the kind of pasture and the season of the year. Undoubtedly on many farms the feeding of silage with pasture would materially aid in maintaining or increasing the milk flow at no great increase in cost per hundred pounds of milk.

TABLE III

Feed Consumed per Cow per Month at Northfield

Kind of feed	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds
Oats	28	29	30	31	30	3	4	3	1	14	21	29	223
Corn	46	41	38	40	28	4	3	2	1	7	37	30	277
Barley	9	9	11	8	8	..	..	1	1	1	9	14	71
Succotash	..	..	..	..	..	..	..	..	..	..	2	2	4
Bran	47	48	59	53	19	1	3	2	4	10	33	40	319
Oilmeal	5	12	8	11	7	..	..	..	..	..	5	7	55
Sugar feed	4	10	11	..	..	..	..	..	..	..	3	2	30
Screenings	6	12	18	14	7	..	..	..	..	8	7	7	79
Mixed hay	231	240	267	314	200	..	5	2	7	8	92	172	1,538
Sorghum	32	10	16	5	..	..	..	..	..	..	3	..	66
Corn fodder	239	198	149	89	10	..	..	47	81	312	330	299	1,754
Corn stover	137	103	78	29	11	..	..	..	..	10	76	115	559
Corn silage	585	558	672	666	409	38	18	9	..	5	375	670	4,005
Roots	..	..	..	..	2	..	..	..	..	4	9	..	15
Pasture, days	..	..	..	..	16	30	31	31	30	29	..	..	167

TABLE IV

FEED CONSUMED PER COW PER MONTH AT HALSTAD

Kind of feed	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds
Oats	53	63	71	75	41	..	..	3	3	14	23	35	381
Corn	14	11	10	7	1	..	..	..	..	..	23	25	91
Barley	38	37	38	48	22	..	1	3	9	19	28	45	288
Rye	4	5	4	3	..	..	..	..	..	..	1	1	18
Bran	15	13	13	8	3	1	..	..	..	..	4	9	66
Shorts	1	1	2	1	..	..	..	..	..	..	..	..	5
Oilmeal	1	1	1	..	..	..	..	..	..	..	..	..	3
Screenings	..	..	5	3	..	..	6	..	..	..	..	..	14
Alfalfa	53	41	26	17	..	4	8	..	21	75	94	169	508
Mixed hay	178	253	337	429	276	14	9	41	32	36	137	121	1,863
Millet	102	49	35	7	..	..	..	..	..	..	32	84	309
Corn fodder	346	291	298	190	37	30	..	6	68	224	310	324	2,124
Corn stover	..	..	..	17	..	..	..	..	..	..	22	..	39
Corn silage	428	425	462	505	285	25	43	59	71	30	236	339	2,908
Roots	3	4	2	..	4	..	..	..	3	18	19	32	85
Pasture, days	..	..	..	..	16	30	31	31	23	8	..	..	139

TABLE V

Feed Consumed per Cow per Month at Cokato

Kind of feed	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds
Oats	32	41	51	48	29	14	15	10	11	19	23	35	328
Corn	68	61	82	78	43	18	15	16	18	24	31	57	511
Barley	13	12	9	15	8	2	..	..	2	4	7	10	82
Bran	25	20	20	27	9	3	3	..	3	8	9	17	144
Shorts	5	6	7	..	7	..	..	..	1	1	6	3	36
Oilmeal	4	4	4	3	..	..	..	..	..	..	1	2	18
Alfalfa	30	15	16	7	..	..	..	2	6	14	37	35	162
Mixed hay	528	487	557	500	100	18	9	7	6	57	325	490	3,083
Corn fodder	15	..	12	2	..	..	4	4	17	17	8	12	91
Corn stover	95	55	30	47	8	..	..	..	..	23	55	111	424
Corn silage	119	119	103	83	26	..	..	..	..	9	56	116	631
Pasture, days	..	..	..	..	27	30	31	31	30	28	..	..	177

TABLE VI

TOTAL GRAIN AND ROUGHAGE PER COW AND PER HUNDRED POUNDS OF MILK PRODUCED, BY MONTHS, AT NORTHFIELD

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds
Grain	145	161	175	157	99	8	10	8	7	40	117	131	1,058
Roughage	639	551	510	437	221	..	5	49	88	330	501	586	3,917
Silage	585	558	672	666	411	38	18	9	..	9	384	670	4,020
Pasture, days	...	...	...	..	16	30	31	31	30	29	..	..	167
Milk produced	492	499	527	513	562	622	480	365	312	336	363	469	5,540
													Average
Grain per 100 pounds of milk	29.4	32.3	33.1	30.6	17.6	1.3	2.0	2.2	2.2	12.0	32.1	28.6	19.1
Roughage per 100 pounds of milk	130.0	110.0	97.0	85.0	39.0	...	1.0	20.0	28.0	98.0	138.0	125.0	70.7
Silage per 100 pounds of milk	119.0	112.0	128.0	130.0	73.0	6.0	4.0	3.0	...	3.0	106.0	144.0	72.5
													Year
Pasture per 100 pounds of milk, days	...	...	...	...	2.8	4.8	6.4	8.5	9.6	8.6	...	...	3.0
													Season
Pasture per 100 pounds of milk, days	...	...	...	...	...	...	...	...	...	...	...	...	5.2

TABLE VII

TOTAL GRAIN AND ROUGHAGE PER COW AND PER HUNDRED POUNDS OF MILK PRODUCED, BY MONTHS, AT HALSTAD

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds
Grain	126	131	144	145	67	1	7	6	12	33	79	115	866
Roughage	679	634	696	660	313	48	17	47	121	335	595	698	4,843
Silage	431	429	464	505	289	25	43	59	74	48	255	371	2,993
Pasture, days	...	...	...	..	16	30	31	31	23	8	..	..	139
Milk produced	409	383	414	406	473	490	447	386	342	369	338	392	4,849
													Average
Grain per 100 pounds of milk	30.8	34.2	34.7	35.7	14.1	...	1.5	1.8	3.5	9	23	30	18.0
Roughage per 100 pounds of milk	166.0	165.0	168.0	162.0	66.0	10	4.0	12.0	35.0	91	176	178	100.0
Silage per 100 pounds of milk	105.0	112.0	112.0	124.0	61.0	5	9.0	15.0	21.0	13	75	95	61.0
Pasture per 100 pounds of milk, days	...	...	...	...	3.4	6	7.0	8.0	6.7	2	...	...	Year 2.8
Pasture per 100 pounds of milk, days	...	...	...	...	...	...	...	...	...	...	...	...	Season 5.5

TABLE VIII

TOTAL GRAIN AND ROUGHAGE PER COW AND PER HUNDRED POUNDS OF MILK PRODUCED, BY MONTHS, AT COKATO

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds
Grain	147	144	173	171	95	37	33	26	36	56	77	124	1,119
Roughage	707	597	649	586	117	18	13	13	29	114	443	686	3,972
Pasture, days	...	...	...	..	27	30	31	31	30	28	..	..	177
Milk produced	362	352	407	459	582	590	502	426	357	330	269	308	4,944
													Average
Grain per 100 pounds of milk	40.6	41	42.5	37.3	16.3	6.5	6.6	6.1	10	17.0	28.6	40	22.6
Roughage per 100 pounds of milk	195.0	170	160.0	128.0	20.0	3.0	2.6	3.0	8	35.0	165.0	223	80.3
													Year
Pasture per 100 pounds of milk, days	...	...	...	...	4.6	5.0	6.2	7.3	8	8.5	...	...	3.5
													Season
Pasture per 100 pounds of milk, days	...	...	...	...	...	...	...	...	...	...	...	...	6.3

Grouping the grains and roughages together shows the total feeds consumed per cow. This is shown by months with the amount of milk produced in Tables VI, VII, and VIII in order to present the relation of feed to product.

The amount of feed required per hundred pounds of milk produced is a convenient factor to know in quickly estimating feed cost. Table IX summarizes the annual average amount of feed per hundred pounds of milk in each of the three localities.

TABLE IX
FEED CONSUMED ANNUALLY PER HUNDRED POUNDS OF MILK

	Northfield	Halstad	Cokato
Grain, lbs.	19.1	18.0	22.6
Roughage, lbs.	70.7	100.0	80.3
Silage, lbs.	72.5	61.0	.....
Pasture, days	3.0	2.8	3.5

Tables X and XI present interesting phases of the feeding practices on the Northfield farms. While the amount of grain consumed per cow is one sixth of the total amount of feed, the cost of the grain constitutes over one third of the cost of feed, not including pasture. More than one third of the grain was purchased in the form of commercial feed and four fifths of this was bran.

TABLE X
FEED CONSUMED PER COW AT NORTHFIELD*

	Feed	Proportion of total feed	Proportion of total cost
	Pounds	Per cent	Per cent
Grain per cow	1,058	16.6	38.4
Roughage per cow†	5,257	83.4	61.6
Total	6,315	100.0	100.0

* Except pasture.
† Three pounds silage equal 1 pound hay.

TABLE XI
PROPORTION OF KINDS OF GRAIN CONSUMED PER COW

Kind of feed	Amount consumed	Proportion of total
	Pounds	Per cent
Oats	227	21.5
Corn	277	26.4
Barley	71	6.7
Screenings	79	7.5
Commercial feeds*	404	37.9
Total	1,058	100.0

* Bran constituted 79 per cent of the commercial feeds.

Tables XII and XIII present additional data regarding the feeding on Halstad farms. Here grain constitutes but one eighth of the number of pounds of feed consumed, but the cost is almost one third of the total feed cost. Only 8 per cent of the grain was purchased in the form of commercial feed and almost nine tenths of this was bran. Farm grains furnished over nine tenths of the grain fed.

TABLE XII

FEED CONSUMED PER COW AT HALSTAD*

	Feed	Proportion of total feed	Proportion of total cost
	Pounds	Per cent	Per cent
Grain per cow	866	12.8	30.5
Roughage per cow†	5,841	87.2	69.5
Total	6,707	100.0	100.0

* Except pasture.

† Three pounds silage equal 1 pound hay.

TABLE XIII

PROPORTION OF KINDS OF GRAIN CONSUMED PER COW

Kind of feed	Amount consumed	Proportion of total
Pounds	Per cent	Per cent
Oats	381	44.0
Corn	91	10.5
Barley	288	33.2
Rye	18	2.1
Screenings	14	1.6
Commercial feeds*	74	8.6
Total	866	100.0

* Bran constitutes 89 per cent of the commercial feeds.

Tables XIV and XV present additional data on feed for the Cokato district. It is noted that the grain was about one fifth of the amount of feed consumed but the cost of the grain was over two fifths of the cost of roughage and grain. These farmers made their grain ration with less than one fifth commercial feed, and of this three fourths was bran. Farm-grown grains constituted over four fifths of the grain consumed.

TABLE XIV

FEED CONSUMED PER COW AT COKATO*

Kind of feed	Feed	Proportion of total feed	Proportion of total cost
		Per cent	Per cent
Grain	1,119	22.0	42.6
Roughage	3,972	78.0	57.4
Total	5,091	100.0	100.0

* Except pasture.

TABLE XV

PROPORTION OF KINDS OF GRAIN CONSUMED PER COW

Kind of feed	Amount consumed	Proportion of total
	Pounds	Per cent
Oats	328	29.5
Corn	511	46.0
Barley	82	6.7
Commercial feeds*	198	17.8
Total	1,119	100.0

* Bran constituted 73 per cent of the commercial feeds.

PRODUCTION OF MILK PER ACRE

Table XVI shows the number of acres required to maintain a cow in the three localities. This is based on the average pounds of feed produced per acre on these farms. It was assumed that the equivalent of the commercial feeds purchased was grown on the farm.

TABLE XVI

ACRES REQUIRED TO MAINTAIN COW

	Northfield	Halstad	Cokato
	Acres	Acres	Acres
Grain	0.82	0.70	0.75
Roughage	1.15	1.13	0.98
Pasture	2.00	2.00	2.00
Total	3.97	3.83	3.73

Table XVII shows the amount of milk produced per acre for the average of the entire year and for the winter and summer seasons. It is assumed that 90 per cent of the milk produced in the summer season was obtained on pasture alone.

TABLE XVII

MILK PRODUCED PER ACRE

	Northfield	Halstad	Cokato
	Lbs.	Lbs.	Lbs.
Annually	1,395	1,265	1,325
Dry crops	1,589	1,403	1,392
Pasture	1,204	1,140	1,268

LABOR

Labor constitutes an important part of the business of producing milk. Not only is a relatively large amount of man labor required but the demand is incessant, varying only slightly from month to month.

It has often been assumed that the calf and the manure will offset the expense of labor and miscellaneous costs. At present prices and with average cows this is not a fair offset for the cost of labor.

From a detailed study of man and horse hours spent on cows in each of the three localities over the years concerned, it was found that the following hours were required to care for the cow and haul the product to the local market. (See Table XVIII.) Most of the milk was marketed in the form of cream for butterfat at local creameries, only a few of the Northfield farmers supplying market milk. On the average, marketing the product required labor three times a week during the summer months and twice a week in the winter. The distance to market averaged three miles.

TABLE XVIII

Hours of Man and Horse Labor per Cow, Annually

Northfield		Halstad		Cokato	
Man	Horse	Man	Horse	Man	Horse
145	40	160	17	132	34

The larger number of man hours at Halstad is accounted for by the smaller number of cows per herd and by the fact that more hours are spent on the cattle in the winter season because of the extreme cold weather. Few of the barns are equipped with water systems for cattle—the result is often hand watering during severe storms. The low number of horse hours is accounted for by coöperative hauling of cream by two of the farms, by the location of one farm within the town limits where the cream is carried by hand but a short distance to the creamery, and by the practice of marketing with automobiles instead of horses.

Purebred herds require much more labor than these figures show, and an estimate for labor on such stock should be from 25 to 50 per cent more. The marketing of whole milk every day would increase the labor requirements per cow on the farms studied by at least 30 man hours and 60 horse hours annually. This should be considered in estimating the cost of producing market milk delivered to the local station.

To figure the labor cost, a rate per hour for man labor and for horse labor must be used. For the years covered by this study, an average rate of 15 cents per hour for man labor and 11 cents for horse labor is a close approximation of the cost. At the present time and for immediate future use this rate should be increased to about 24 cents per hour for man labor and 15 cents for horse labor.

To illustrate the constant demand throughout the year for labor, by the dairy business, Table XIX is presented.[2]

TABLE XIX

AVERAGE HOURS OF LABOR FOR MAINTENANCE REQUIRED MONTHLY PER COW*

Month	Northfield		Halstad	
	Man	Horse	Man	Horse
	Hours	Hours	Hours	Hours
January	13.6	3.2	13.2	2.4
February	12.8	3.1	11.8	2.2
March	13.8	3.7	13.1	2.6
April	13.1	3.2	12.8	1.8
May	10.7	3.2	12.3	1.3
June	9.8	3.0	10.0	1.2
July	9.5	2.7	10.6	1.1
August	9.0	2.8	10.2	1.0
September	8.8	3.0	9.3	0.8
October	8.8	2.8	11.4	1.4
November	10.3	3.0	12.4	1.6
December	13.2	3.2	13.4	2.2
All months	11.1	3.0	11.7	1.6
Seven active months	9.9	2.9	11.0	1.2
Five inactive months	12.8	3.2	12.8	2.2

* The average number of cows in the farm groups was 12.9 at Northfield and 8.7 at Halstad.

BUILDING OR SHELTER

The building cost per cow is more or less of an approximation. An accurate charge is difficult to make because of the wide variation in the type and cost of buildings found on these farms and the use to which the barns and sheds were put during the year. In this study the barn used for cows, or the portion occupied by them, the silo, and the milk house were the buildings considered as being concerned in the dairy business. Inasmuch as on all of these farms the barns were used for storage of feed and not for sale-crops, no deduction was made. The barn was considered as a unit and the annual charge was divided by the total number of animal units housed to obtain the cost per unit. One horse or one cow was considered as a unit, and two head of young cattle or two colts as a unit. The annual charge for the silo was divided by the cattle units and the charge for the milk house, by the number of cows.

The annual charges that enter into the building cost are: interest on depreciated average investment, depreciation, insurance, taxes, and repairs.[3] Interest should be charged at 6 per cent. Depreciation may be figured at 3 per cent on frame buildings, and 2.5 per cent on cement structures. Silos have been depreciated at the rate of 3 per cent. Taxes have been estimated at 0.5 per cent on the depreciated value, and insurance at the value and rate used in the locality. The sum of these charges on the various buildings constitutes the annual building expense.

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[2] Boss, Andrew, Peck, F. W. and Cooper, T. P. Labor requirements of livestock Minn. Agr. Exp. Sta. Bull. 161. 1916.

The average value of the barns used for the stock on the farms included was estimated at $1,350. The silos were valued at an average of $250, being mostly of the stave type. Only three of the farms had separate milk houses. These were poorly built and were not considered in the average building cost in this study. The average number of animal units housed by the barns at Northfield was 33; at Halstad, 29; and at Cokato, 37. The silos fed an average of 26 cattle units at Northfield. Three silos at Halstad fed an average of 25 units and two silos at Cokato furnished feed for an average of 32 cattle units. Considering the Northfield group as an example, the following illustrates the method used in estimating the annual building or plant cost.

Average barn value	$1,350.00	
Barn: Interest on depreciated average investment—$695.27 at 6 per cent	41.72	
Depreciation—3 per cent of estimated value	40.50	
Taxes and insurance—1 per cent of estimated value	13.50	
Repairs—based on actual cost on these farms	15.00	
Total	$110.72	
Average barn cost per unit (33 units)		3.36
Average silo value	275.00	
Silo: Interest on depreciated average investment—$141.63 at 6 per cent	8.50	
Depreciation—3 per cent of estimated value	8.25	
Taxes and insurance—1 per cent of estimated value	2.75	
Repairs (no record of cash repairs)	......	
Total	$19.50	
Average annual silo cost per unit (26 units)		0.75
Total barn and silo cost per cow		$4.11

EQUIPMENT

The equipment cost consists of the annual charge for the use of all equipment used in milk or butterfat production, and includes such equipment as separators, milking machines, pails, cans, strainers, milk scales, feed carts, and miscellaneous barn and milk house items. Where a special conveyance was maintained for hauling the milk or cream this was invoiced as dairy equipment. But one farm in this study used a milking machine and this was excluded in computing the equipment cost.

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[3] Depreciated average investment is found by first assuming a certain rate of depreciation. A rate of 3 per cent means the building will last 33 years. To the cost of the building add the value at the beginning of the last year. Divide by 2 to obtain depreciated average investment.

Example: Barn cost $3,000, depreciation 3 per cent; at beginning of the thirty-third year the barn's value would be $90.09. $3,000+$90.09=$3,090.09. $3,090.09÷2=$1,545.05, depreciated average investment.

Interest, depreciation, and repairs make up the annual cost of equipment. The average annual investment of dairy equipment per farm was $41.51 at Northfield; $53.93 at Halstad; and $73.06 at Cokato; with an average for the three localities of $56.35. The annual cost would be computed as follows:

Interest on $56.35 at 6 per cent	$ 3.38
Depreciation at 10 per cent	5.64
Repairs (amounting to 2.8 per cent)	1.56
Total annual cost	$10.58
Average number of cows per farm	13.5
Equipment cost per cow	$ 0.78

BEDDING

Straw was used for bedding on all the farms in this study, and was raised on the farms. It was not considered an important item and it was not possible to obtain accurate or reliable data on this factor. It has been roughly estimated for several of the farms that a ton of straw was used annually per cow for bedding. Larson states that a cow in eight months will use 1,200 pounds of wheat straw, 3,000 pounds of sawdust, or 1,050 pounds of shavings.[4] When straw has a ready sale as it had in 1917, the item of bedding becomes important from a cost standpoint. Allowing for waste in bedding, the estimate of a ton of straw per cow is believed to be fair and equitable. Ordinarily the value of straw will not exceed $2 per ton, but at present prices $4 or $5 per ton or per cow is a fairer charge.

GENERAL EXPENSE

Under General Expense are grouped such items as cost of medicine, stock food, salt, veterinary fees, cow-testing association fees, interest on purchased feed, water and light if purchased by meter, ice, fuel for heating boiler, gasoline for engines, and various other items of the same character. The water cost on the farms studied was assumed to be covered in the building investment. During the years of this investigation the cash record of such items as those mentioned was kept under the heading Cash Sundries. However, none of the farmers were members of a cow-testing association; none used ice for cooling the milk. Water tanks were used and are included under Equipment. No boilers were used to consume fuel, and gasoline was charged with the equipment maintenance. The cash cost of sundries per cow on these farms amounted to 78 cents at Northfield; 36 cents at Halstad; and 61 cents at Cokato. A member of a testing association is usually charged $1.50 per cow for testing and this should be included. It is believed that on the average dairy farm a charge of $1.50 per cow will cover the general items of expense. To this should be added a testing fee of $1.50 if the farmer is a member of a testing association. In specialized dairies, fully equipped, this item will be larger. No estimate can be made that will cover such individual cases.

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[4] Larson, C. W. Milk production cost accounts. Columbia University Press. 1916.

MANAGERIAL SUPERVISION AND OVERHEAD CHARGES

To be successful, a dairy business demands skilled supervision. The farmer who plans the ration, records the production, and oversees the breeding of the cows is entitled to more than hired man's wages. He may not always earn more but he deserves more, and an allowance should be made to cover this supervisory work as a cost. Moreover, every productive enterprise on the farm must be charged with its proper share of such items as telephone cost, stationery, advertising, postage, miscellaneous labor, and so on. These are really overhead charges of the entire farm business. Investigations conducted by the Office of Farm Management, United States Department of Agriculture, indicate that 10 per cent of the total operating cost is a fair estimate for supervision and general overhead expense.[5] This rate is used in the application of the factor data in Part II.

CREDITS

The following items have been considered proper credits to the cow: (1) calf; (2) manure; (3) milk.

CALF

The value of a grade calf four days old has been estimated at various prices on the farms studied. Some male calves were killed at birth or soon after; others were sold at a dollar; and some were raised. At present prices a valuation of $5 is warranted. This figure is used in Part II in estimating the calf credit.

MANURE

Manure is a most difficult item on which to base an estimate of value. The amount produced depends on several factors, namely, size of cow, kind and amount of feed, and kind and amount of bedding used. Even tho the amount produced is closely estimated, the amount saved and applied to the field is usually different. Probably on the average not over 60 per cent of the total elements voided, plus the straw used for bedding, is applied to the fields. The best measure of manure value is in terms of increased yields on the land to which it is applied. This requires accurate records over a term of years. Even this value would vary with the topography of the land, season of year applied, kind of crop grown, and finally with the price of the product. At present prices of crops any appreciable increased yield would doubtless bring the value of manure higher than it has ever been estimated. Based on the market value of its fertilizer elements, the price becomes entirely out of proportion with all other factors and would not be a safe figure to use.

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[5] Story, G. F. E. and Tubbs, W. J. The cost of producing market milk in 1916-17 on 212 Vermont farms. Vermont Agr. Exp. Sta. Bull. 209. 1917.

Warren quotes Roberts as saying that a 1,000-pound cow will void 13.5 tons of manure annually, with bedding, 14.6 tons.[6] Assuming 70 per cent was saved on these farms, gives 10.2 tons per cow. Considering 1917 prices of feedstuffs and the value of bedding, this manure could very reasonably be given a value of $2 per ton at the barn. This will allow a credit of $20.40 per cow.

The United States Department of Agriculture is now using the increase-in-crop method of estimating manure value.[7] The average value of crops grown on well-stocked Pennsylvania farms is given as $15.80 per animal unit more than that received on farms with few animals. Manure from all farm animals was included in this study. Similar studies in Michigan indicate an increase in value of crops of $8.22 per animal unit. The difference is accounted for by the greater need for fertility by the Pennsylvania soil and by the better care given the manure on the Pennsylvania farms. This illustrates the effect of conditions on the value of manure and means that accurate calculations depend on knowing the conditions and methods of management in each particular case. Under conditions as found on most Minnesota farms where the manure is handled reasonably well, with present values of feed and bedding, the credit per cow should amount to $20 per year for added fertility.

MILK

The production of milk and butterfat is the main item of credit. It is given in Table II by months, with the total for the year for each group of cows. Bringing together the yearly totals shows the average annual production per cow in each locality and the grand average for all cows.

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[6] Warren, G. F. Farm management, page 198. 1913.

[7] U. S. Dept. of Agr. Prof. papers Bull. 341, page 96. 1917.

TABLE XX

ANNUAL PRODUCTION OF MILK AND BUTTERFAT PER COW

	Northfield	Halstad	Cokato	Av. all cows
Milk, lbs.	5,540.0	4,849.0	4,944.0	5,153.0
Butterfat, lbs.	190.0	205.6	206.4	200.8
Average test, per cent	3.43	4.23	4.17	3.89

PART II

APPLICATION OF FACTOR DATA IN COMPUTING THE COST OF MILK PRODUCTION

To approximate the cost of milk at any certain time or for any certain period, current prices must be used on known quantities. The changing factor in cost is price. The amounts of feed consumed by cows of similar production do not vary greatly. The hours of labor are fairly constant and the miscellaneous items can safely be estimated by knowing the proportions of the various costs. It is not claimed that such methods of ascertaining costs are exactly accurate. They are a close approximation, however, which is the best that can be done under such widely fluctuating conditions as exist at present.

Using the figures in Part I for each locality as the basis for computing the cost of milk, illustrations are here presented of the application of the data. The farm prices for most of the feeds are based on market prices on January 1, 1918. For those feeds on which prices are not quoted on the markets, such as corn silage, fodder, and stover, a price is assumed, based on the comparative feeding value. Prices for fodder and stover are based on the feeding value of bran at current prices for that feed. The price for pasture is estimated at 6 per cent on $125 land at Northfield, $100 land at Cokato, and $75 land at Halstad. Two acres are allowed per cow for pasture.

COST OF MILK AT NORTHFIELD

In order to apply the material in Part I to the Northfield cows, the following factors are used:

(a) Cows are valued at an average price of $100 as producers and $60 as beef.

(b) The average number of cows per farm was 15.

(c) As most of the farms possess silos, this charge is included in the building cost.

(d) As all of these farmers are now members of a cow-testing association, a fee of $1.50 is added to the general expense.

(e) Land in pasture is valued at $125 per acre.

Table XXI presents the cost of feed per cow at Northfield.

TABLE XXI
Cost of Feed per Cow at Northfield

Kind of feed	Price on Jan. 1, 1918	Price per pound	Amount consumed per cow*	Cost of feed
	Bu. or ton	Cents	Pounds	
Oats	$0.80	2.5	223	$5.58
Corn	1.50	2.2	277	6.09
Barley	1.35	2.8	71	1.99
Succotash (46 pounds)	1.30	2.7	4	0.11
Bran	36.00	1.8	319	5.74
Oilmeal	60.00	3.0	55	1.65
Sugar feed	54.00	2.7	30	0.81
Screenings	24.00	1.2	79	0.95
Mixed hay	18.00	0.9	1,538	13.84
Sorghum	8.00	0.4	66	0.26
Corn fodder	10.80	0.54	1,754	9.47
Corn stover	4.00	0.2	559	1.12
Corn silage	6.00	0.3	4,020	12.06
Total cost	....	...	....	$59.67

* From Table III. Local prices Jan. 1, 1918, are applied to compute the cost.

The statement of cost appears as follows:

Feed:		
Grain, 1,058 lbs. at 2.16 cents per lb.	$22.92	
Roughage, 3,917 lbs. at $12.60 per ton	24.69	
Silage, 4,020 lbs. at $6.00 per ton	12.06	
Pasture, 2 acres at $7.50 per acre	15.00	
Total feed cost		$74.67
Labor: (See Table XVIII)		
Man labor, 145 hours at 24 cents	$34.80	
Horse labor, 40 hours at 15 cents	6.00	
Total labor cost		$40.80
Miscellaneous:		
Cow cost (See page 9)	$14.56	
Sire (See page 10)	4.00	
Buildings (See page 23)	4.11	
Equipment (See page 24)	0.52	
Bedding (See page 24)	4.00	
General expense (See page 24) .. plus $1.50	2.28	
Total miscellaneous cost		$29.47
Total operating cost		$144.94
Supervision and general overhead charges, estimated at 10 per cent of other costs (See page 25)		$14.49
Grand total cost		$159.43

Credits:		
Calf (See page 25)	$ 5.00	
Manure (See page 25)	20.00	
Total credits		25.00
Net cost		$134.43
Annual production of milk per cow, lbs. (See page 27)		5,540
Average annual cost per hundred pounds		$2.42
Average annual cost per quart		0.052

Because of the variation in the cost of producing milk from month to month, the year is divided into two seasons of six months each: a winter feeding period, November to April, inclusive, and a summer feeding period, May to October, inclusive. The cost of feed is the large fluctuating factor. It is assumed here that the other costs are equal for each season, altho as a matter of fact more labor is spent on cows in the winter season. Computations made as follows show the cost of milk for each period.

(a) The cost of feed for each season of six months is computed.

(b) From the difference between the grand total annual cost and the feed cost are subtracted the credits of calf and manure.

(c) This sum is divided by two and each season is charged with its half of the costs.

(d) The net cost of milk for each season is divided by the amount of milk produced in that season.

PROCESS OF COMPUTING SEASONAL COST PER COW UNDER NORTHFIELD CONDITIONS

Winter Season (November to April, Inclusive)

Feed: (See Table VI)		
Grain, 886 lbs. at 2.16 cents per lb.	$19.14	
Roughage, 3,224 lbs. at $12.60 per ton	20.34	
Silage, 3,535 lbs. at 6.00 per ton	10.61	
Total feed cost		$50.09
Other costs (one half of all other costs less credits)		29.88
Net cost		$79.97
Pounds of milk produced per cow—November to April (See Table II)		2,863
Average cost per hundred pounds, winter season		$2.79
Average cost per quart, winter season		0.0598

Summer Season (May to October, Inclusive)

Total annual feed cost is given as $74.67—	
$74.67 less $50.09 (winter feed cost) equals summer feed cost	$24.58
Summer season share of other costs	29.88
Net cost	$54.46

Pounds of milk produced per cow, May to October (See Table II)	2,677
Average cost per hundred pounds, summer season	$2.03
Average cost per quart, summer season	0.0436

PROPORTION OF COSTS

Table XXII shows the relation of the groups of costs to the total cost. The feed is by far the major cost, amounting to approximately half of the annual total cost.

TABLE XXII

PROPORTION OF COSTS AT NORTHFIELD

	Feed	Labor	Misc.*	Total
	Per cent	Per cent	Per cent	Per cent
Year	46.8	25.6	27.6	100
Winter season	54.1	22.0	23.9	100
Summer season	36.7	30.4	32.9	100

* Includes supervision and general overhead charges.

The producer of market milk has costs to meet other than those sustained by those who sell the product to creameries in the form of butterfat. Chief among these costs are hauling labor and equipment. The farmers near Northfield who produce milk for shipping have an investment in equipment such as milk cans, cooling apparatus, and hauling equipment amounting to an annual cost of at least one dollar per cow. Labor is the large item of increased expense, however, and an allowance was estimated in Part I, page 21, of an additional 30 man hours and 60 horse hours per cow to cover this expense. Applying the rate of 24 cents per hour for man labor and 15 cents for horse labor makes a cost of $16.20 for additional labor. Adding a dollar for equipment brings the estimated increased cost to $17.20 per cow. Adding 10 per cent of this cost for supervision and general overhead charges brings the total increased cost to $18.92 per cow. Dividing this sum by the average annual production of milk (5,540 pounds), makes a marketing cost of 34 cents per hundred pounds. This would bring the annual cost of milk to $2.76 per hundred pounds under Northfield conditions. For the winter season, the cost on this basis is $3.13 per hundred pounds, and for the summer season, $2.37 per hundred pounds.

COST OF MILK AT HALSTAD

The following factors ars used to fit present conditions on the Halstad farms:

(a) Value of cow as producer, $75; for block, $40.

(b) Average number of cows per farm, 10.

(c) No silo charge is included in the building cost as only three farms possessed silos.

(d) Land as pasture valued at $75 per acre.

Table XXIII presents the cost of feed per cow at Halstad.

TABLE XXIII

COST OF FEED PER COW AT HALSTAD

Kind of feed	Price on Jan. 1, 1918	Price per pound	Amount consumed per cow*	Cost of feed
	Bu. or ton	Cents	Pounds	
Oats	$0.72	2.2	381	$8.38
Corn	1.50	2.2	91	2.05
Barley	1.30	2.7	288	7.78
Rye	1.85	3.1	18	0.56
Bran	37.00	1.85	66	1.22
Shorts	37.00	1.85	5	0.09
Oilmeal	62.00	3.1	3	0.09
Screenings	24.00	1.2	14	0.17
Alfalfa	25.00	1.25	508	6.35
Mixed hay	18.00	0.9	1,863	16.77
Millet	15.00	0.75	309	2.32
Corn fodder	11.00	0.55	2,124	11.68
Corn stover	4.00	0.2	39	0.08
Corn silage	6.00	0.3	2,908	8.72
Roots	4.00	0.2	85	0.17
Total cost	....	...	....	$66.43

* From Table IV. Local prices Jan. 1, 1918, are applied to compute the cost.

Summarizing the costs in tabular form the statement would appear as follows:

Feed:			
Grain,	866 lbs. at 2.34 cents per lb.	$20.34	
Roughage,	4,843 lbs. at $15.36 per ton	37.20	
Silage and roots,	2,993 lbs. at 5.95 per ton	8.89	
Pasture, 2 acres at 6 per cent (on $75 land)		9.00	
Total feed cost			$75.43
Labor: (See Table XVIII)			
Man labor, 160 hours at 20 cents		32.00	
Horse labor, 17 hours at 12 cents		2.04	
Total labor cost			34.04
Miscellaneous:			
Cow cost	(See page 9)	$11.74	
Sire	(See page 10)	4.00	
Buildings	(See page 23)	3.81	
Equipment	(See page 24)	1.01	
Bedding	(See page 24)	4.00	
General expense	(See page 24)	0.36	
Total miscellaneous cost			24.92
Total operating cost			$134.39
Supervision and general overhead charges, estimated at 10 per cent of other costs (See page 25)			$13.44
Grand total cost			$147.83

Credits:		
Calf (See page 25)	$ 5.00	
Manure (See page 25)	20.00	
Total credits		25.00
Net cost		$122.83
Annual production of milk per cow, lbs. (See page 27)		4,849
Average annual cost per hundred pounds		$2.53
Average annual cost per quart		0.0544

Computing the cost by seasons, as was done with the Northfield cows, the statement appears as follows for the Halstad farms:

Winter Season (November to April, Inclusive)

Feed: (See Table VII)		
Grain, 740 lbs. at 2.34 cents per lb.	$17.32	
Roughage, 3,962 lbs. at $15.36 per ton	30.44	
Silage, 2,455 lbs. at 5.95 per ton	7.30	
Total feed cost		$55.06
Other costs (one half all other annual costs, less credits)		23.70
Net cost		$78.76
Pounds of milk produced per cow, winter season (See Table II)		2,342
Average cost per hundred pounds, winter season		$3.36
Average cost per quart, winter season		0.0721

Summer Season (May to October, Inclusive)

Total annual feed cost is given as $75.43—	
$75.43 less $55.06 (winter feed cost) equals summer feed cost	$20.37
Summer season share of other costs	23.70
Net cost	$44.07
Pounds of milk produced per cow, summer season (See Table II	2,507
Average cost per hundred pounds, summer season	$1.76
Average cost per quart, summer season	0.0378

PROPORTION OF COSTS

Table XXIV shows the relation of the groups of costs to the total cost. It is noted that feed is the major cost, amounting to approximately one half on the year basis.

TABLE XXIV

Proportion of Costs at Halstad

	Feed	Labor	Misc.*	Total
	Per cent	Per cent	Per cent	Per cent
Year	51.0	23.0	26.0	100
Winter season	60.3	18.6	21.1	100
Summer season	36.0	30.0	34.0	100

* Includes supervision and general overhead charges.

COST OF MILK AT COKATO

To provide the fundamental data for using the material in Part I for the Cokato cows the following factors are used:

(a) Cows are valued at an average price of $85 as producers and $45 for beef.

(b) The average number of cows per farm was 15.

(c) No silo charge is included in the building cost, as only two farms possessed silos.

(d) Land in pasture is estimated at $100 per acre.

Table XXV presents the cost of feed per cow at Cokato.

TABLE XXV

COST OF FEED PER COW AT COKATO

Kind of feed	Price on Jan. 1, 1918	Price per pound	Amount consumed per cow*	Cost of feed
	Bu. or ton	Cents	Pounds	
Oats	$0.80	2.5	328	$8.20
Corn	1.40	2.0	511	10.22
Barley	1.35	2.8	82	2.30
Bran	36.00	1.8	145	2.61
Shorts	36.00	1.8	35	0.63
Oilmeal	60.00	3.0	18	0.54
Alfalfa	25.00	1.25	162	2.02
Mixed hay	18.00	0.9	3,083	27.75
Corn fodder	10.80	0.54	91	0.49
Corn stover	4.00	0.2	424	0.85
Corn silage	6.00	0.3	637	1.91
Total cost	....	...	....	$57.52

* From Table V. Local prices Jan. 1, 1918, are applied to compute the cost.

The statement of cost appears as follows:

Feed:			
Grain,	1,119 lbs. at 2.19 cents per lb.	$24.50	
Roughage,*	3,972 lbs. at $16.62 per ton	33.02	
Pasture,	2 acres at $6.00 per acre	12.00	
Total feed cost			$69.52
Labor: (See Table XVIII)			
Man labor,	132 hours at 24 cents	31.68	
Horse labor,	34 hours at 15 cents	5.10	
Total labor cost			36.78
Miscellaneous:			
Cow cost	(See page 9)	$13.39	
Sire	(See page 10)	4.00	
Buildings	(See page 23)	3.00	
Equipment	(See page 24)	0.91	
Bedding	(See page 24)	4.00	
General expense	(See page 24)	0.61	
Total miscellaneous cost			25.91

* Three lbs. silage equivalent to 1 lb. hay.

Total operating cost		$132.21
Supervision and general overhead charges, estimated at 10 per cent of other costs (See page 25)		$13.22
Grand total cost		$145.43
Credits:		
Calf (See page 25)	$ 5.00	
Manure (See page 25)	20.00	
Total credits		25.00
Net cost		$120.43
Annual production of milk per cow, lbs. (See page 27)		4,944
Average annual cost per hundred pounds		$2.43
Average annual cost per quart		0.0522

PROCESS OF COMPUTING SEASONAL COST PER COW UNDER COKATO CONDITIONS

Winter Season (November to April, Inclusive)

Feed: (See Table VIII)		
Grain, 836 lbs. at 2.19 cents per lb.	$18.31	
Roughage, 3,668 lbs. at $16.62 per ton	30.48	
Total feed cost		$48.79
Other costs (one half of all other annual costs, less credits)		25.47
Net cost		$74.26
Pounds of milk produced per cow, November to April (See Table II)		2,157
Average cost per hundred pounds, winter season		$3.44
Average cost per quart, winter season		0.0738

Summer Season (May to October, Inclusive)

The total annual feed cost is given as $69.52—

$69.52 less $48.79 (winter feed cost) equals summer feed cost	$20.73
Summer season share of other costs	25.46
Net cost	$46.19
Pounds of milk produced per cow (See Table II)	2,787
Average cost per hundred pounds, summer season	$1.65
Average cost per quart, summer season	0.0354

PROPORTION OF COSTS

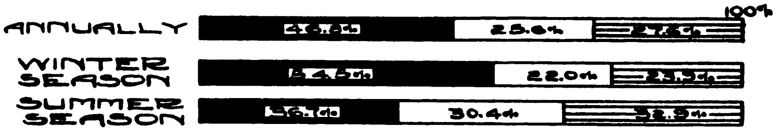
Table XXVI shows the relation of each group of costs to total cost and to each other group. Feed constitutes the major cost, especially during the winter season.

TABLE XXVI

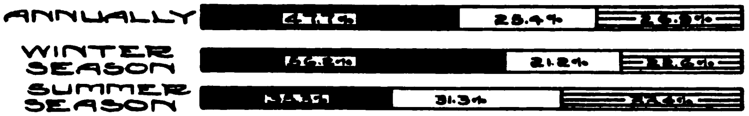
Proportion of Costs at Cokato

	Feed	Labor	Misc.*	Total
	Per cent	Per cent	Per cent	Per cent
Year	47.7	25.4	26.9	100
Winter season	56.2	21.2	22.6	100
Summer season	35.3	31.3	33.4	100

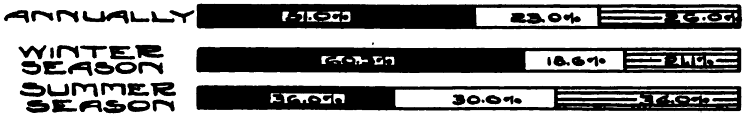
* Includes supervision and general overhead charges.



PROPORTION OF COSTS AT NORTHFIELD



PROPORTION OF COSTS AT COKATO



PROPORTION OF COSTS AT HALSTAD.

TABLE XXVII

Summary of Cost per Hundred Pounds of Milk

	Northfield	Halstad	Cokato
Year	$2.42	$2.53	$2.43
Winter season	2.79	3.36	3.44
Summer season	2.03	1.76	1.65

Table XXVII summarizes the cost per hundred pounds of milk in the three localities for the year and for the two seasons. There is a very close relation between the three groups in the average annual cost but considerable difference in the seasonal costs. The large factor influencing this fluctuation in cost is the varying amount of milk produced in the two seasons. At Northfield, winter production is emphasized. The majority of the cows freshen in the fall with the result that 52 per cent of the milk is obtained in the six months from November to April. This accounts for the relatively small difference between the winter and summer cost of milk.

There is a much larger difference in cost per hundred pounds between the two seasons at Halstad and Cokato than at Northfield. This is because a greater quantity of milk is produced during the summer season. The cows are not pushed for milk during the heavy feeding season. More cows freshen in the spring, especially at Cokato. This means summer dairying. In the Halstad group, 52 per cent of the milk is obtained in the summer season, which with the low cost of maintenance means a lower cost per hundred pounds of milk. At Cokato, 57 per cent of the milk is produced during the summer months and this explains the cost per hundred pounds being approximately one half of the winter cost.

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The University of Minnesota

AGRICULTURAL EXPERIMENT STATION

EAR TYPE SELECTION AND YIELD IN CORN

BY

P. J. OLSON, C. P. BULL, AND H. K. HAYES

DIVISION OF AGRONOMY AND FARM MANAGEMENT

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EAR TYPE SELECTION AND YIELD IN CORN

By P. J. Olson, C. P. Bull, and H. K. Hayes

INTRODUCTION

Superficially, nothing could be much more plausible than the corn score card. The man who feeds corn, hence, the man who puts it to its ultimate use, when confronted with samples of ear corn will select the one that represents the *largest amount* of *sound corn.* Therefore the man who grows corn aims to produce that type which fulfils this requirement. It can very readily be demonstrated that the maximum possible yield of shelled corn is to be found in an ear which is large, cylindrical in shape, has deep kernels, minimum space between the rows of kernels, and maximum filling of butts and tips. What, then, would seem more reasonable than to have before one a standard, a mental score card, embodying these features, and to select carefully toward it, in the hope of producing a crop consisting of that type of ears?

The man who attempted to improve his corn by this type of selection, however, frequently found his immediate results disappointing. The yields from ears which approached the score-card ideal were not strikingly superior to those produced by mediocre ears. Furthermore, no marked increase in the percentage of these "near ideal" ears in the progeny of ears of corresponding parentage was noted.

The failure to obtain immediate results was readily explainable on the basis of the open pollination of the corn plant, which renders impossible any knowledge of the male parent of any selected ear. Furthermore, when ear selection was carried on without any reference to the character of the plant itself, knowledge even of the female was, at best, imperfect. These facts, however, are not sufficient to explain failure to obtain results when the selection is continued for some time. The percentage of ears approaching the ideal should increase as a result of continued selection, and unless this type of ear is definitely correlated with some undesirable plant character, the hoped-for increase in yield should be obtained regardless of the above facts.

The failure on the part of earlier corn breeders to obtain indications of progress, therefore, has suggested the need of definite experimental tests, directly attacking the question of the relation of ear type to yield. Experimentation of this nature began about twelve years ago. The final results of the most extensive investigations have been reported within the last few years. In the main they are corroborated by the results presented in this bulletin, which embodies data of a somewhat different character from those collected by other investigators and describes investigations covering a period of eleven years.

The reasons why ear selection is attended with results of the character indicated are now pretty well understood by students of heredity. An attempt is made in this bulletin to explain these in a way that will help clear up the otherwise rather perplexing question in the mind of the corn breeder.

REVIEW OF PREVIOUS WORK

Definite investigation of the relation between ear characters and yield seems to date back to about 1904. Montgomery (1909) reported a comparison between a rather long, smooth type of ears selected from Reid's Yellow Dent, and the standard type of this variety, which was much less elongated and comparatively rough. As an average of four years, beginning with 1905, selection having been begun in 1904, a difference of 4.4 bushels per acre in favor of the smooth type was obtained.

In the same publication, Montgomery also reported a study of the relation between size of ear and yield. In 1906, 204 ears were planted by the ear-to-row method, each ear having first been weighed. A part of each ear was saved and planted in the same way in 1907. No relation between the weight of the parent ears and the yield of respective rows was found in either year. Another test of this relation was made by determining the average weight of ears in each of the progenies during both years. This test, like the first, brought out no relation. Low-yielding rows averaged as high in size of ears as high-yielding ones, and the percentage of large ears was as high in low-yielding as in high-yielding rows.

The first comprehensive and exhaustive test of the relation of ear characters to yield was made by Williams and Welton (1909, 1915). The types used were long and short, cylindrical and tapering, bare and filled tips, rough and smooth dented, heavy and light, high and low shelling percentage, high, low, and medium number of rows. The following, in brief, are the results reported.

Long vs. short ears.—As an average for ten years there was a difference of 1.39 bushels per acre in favor of the long ears. This difference was regarded by the authors themselves as "no greater than might have been expected had the seed used been identical."

Cylindrical vs. tapering.—A difference of 1.65 bushels in favor of tapering ears was obtained as an average for nine years. The authors regarded this as being within the limits of experimental error.

Bare vs. filled tips.—As an average for eight years a difference of 0.34 bushels was shown. The authors concluded that "this sort of selection . . . has been barren of important results."

Rough vs. smooth dented.—As an average for seven years a difference of 1.76 bushels in favor of the smooth type was found. In their conclusions the authors state that "it would seem that if ears are in all other particulars suitable for seed purposes, smoothness of type should not be regarded as sufficient grounds upon which to discard them."

Heavy vs. light ears.—Two tests, an ear-to-row test and a plot test, were reported in 1909. Continued trial was not reported in 1915. In the ear-to-row test the heaviest 40 per cent of 400 ears was compared with the lightest 40 per cent. A difference of 2.08 bushels in favor of the heaviest was obtained as an average for three years. The authors regarded this as significant.

The plot test consisted of a comparison between 50 representative heavy ears and 50 representative light ears. A difference of 1.93 bushels in favor of the heavy ears was obtained as an average for two years. The authors were unwilling to draw a positive conclusion from this test alone, but stated that "the two tests taken together would seem to indicate a value for the heavy-weight ear."

High vs. low shelling percentage.—As an average for six years a difference of 0.42 bushel in favor of the ears of low shelling percentage was recorded. This practically amounts to no difference.

High, low, and medium number of rows.—Ears with 14, 16, and 18 rows, respectively, were compared for a period of five years. The test was carried on at three stations. At two of them the 14-row ears led while at the other the highest yield was obtained from the 16-row ears. The authors concluded that "with this as with the other ear characters the yield is but slightly affected by this type of selection."

Pearl and Surface (1910) presented the following comparison which is typical of several reported in their bulletin. A group of five excellent ears of sweet corn was compared with a group of five very inferior ones. The two groups are illustrated in their paper and the difference between them is very striking. The resulting yields of each of these groups showed a difference of 1.1 bushels per acre in favor of the good type.

These ears were also compared with reference to the amount of good corn produced by each. It was found that the crop from the good ears showed no larger percentage of the total shelled corn on ears of A-1 quality than did the crop from the poor ears. Again, the crop from the good ears produced essentially the same percentage of its total shelled corn on ears too poor for seed, as did the crop from the poor ears.

Pearl and Surface have also collected a large number of data bearing on the relation of weight of ears to yield. Not all of these have been compiled. The writers have made certain compilations from them, which are presented in another part of this bulletin. They show no relation.

The following partial quotation of these investigators is extremely pointed, "The large, well-tipped, beautifully shaped ear is just as likely as not to be a poor yielder when planted. This result means that the external visible characters are a very unreliable indication of its worth for seed purposes."

Love (1912) reported on correlation studies involving several ear characters and yield per stalk. His test included two varieties and covered a period of two years. The following are the characters studied and the results obtained:

Length of ear and yield.—"A slight advantage in favor of the long ear." Computations indicate a positive correlation which, however, is of doubtful significance.

Weight of ear and yield.—A slight advantage for the heavy ears is indicated in three out of four comparisons. The author's figures show that the average difference amounts to 1.6 bushels per acre in favor of the heavier ears, on the basis of a yield of 50 bushels per acre.

Number of rows and yield.—In three cases the advantage is with the smaller number of rows and in one with the larger number. In other words, the correlation is negative in three instances and positive in one. The correlation is of a significant degree in only one or possibly two cases, however. Therefore, as the author himself concludes ". . . the number of rows does not have much influence upon yield."

Average weight of kernel and yield.—No relation is indicated.

Ratio of tip circumference to butt circumference and yield.—Are tapering or cylindrical ears the highest yielding? No relation is indicated. Shape of ear has no influence on yield. Data for one year only are presented.

Shelling percentage and yield.—Data for one year only and with one variety only, show slight negative correlation.

Funk (1912), in comparing a smooth with a rough type, found that in one test the smooth outyielded the rough six years out of seven, and in another the smooth led five years out of seven.

Cunningham (1915) made a study of the following ear characters as related to yield: Length, circumference, filling of tips, rounding of butts, roughness or smoothness of kernel indentation, shelling percentage, and number of rows. The data were compiled into three groups representing respectively upper, lower, and average ears with reference to each of the above characters. Several varieties entered into the test. The results were as follows:

Long, medium, and short ears, as an average of nine varieties, gave practically equal yields. The author noted, however, that of the earlier maturing ears the longer ones led, while of the later maturing ones the opposite was true.

With reference to circumference, a slight advantage in favor of the smaller ones was noted.

Results for filling of tips and for rounding of butts indicated no influence upon yield.

Comparison of very rough, medium rough, and smooth types showed that while the smooth outyielded the rough in all of the eight varieties, the medium rough led both in the majority of them.

Between shelling percentage and yield no relation was indicated. Number of rows bore a negative or inverse relation to yield in four of the seven varieties. In the other three, the ears with average or medium number of rows led. The author noted that the latter were comparatively early maturing varieties.

While this bulletin deals with ear characters only, it is of interest to note in this connection an investigation which has been made into the relation between other corn plant characters and yield, since the principle illustrated is the same in both cases.

The most complete investigation of this kind, as far as the writers are aware, is that by Ewing (1910). He worked with the following characters: diameter of stalk, length of leaf, breadth of leaf, height of mature plant, height of seedlings, number of internodes below the ear, length of ear at appearance of silks, and number of branches in the tassel. He used weight of grains per stalk as his measure of yield. Among his conclusions, those which are pertinent to the present discussion are as follows: "In the case of none of the characters discussed above has the coefficient of correlation with yield been found sufficiently great to be of much value as an index to selection. No single character has shown itself so closely connected with yield of grain as to stand out as a safe guide to the breeder."

INVESTIGATION AT THE MINNESOTA EXPERIMENT STATION

The investigation involves data obtained from two distinct lines of experimental work: (1) A series of breeding experiments in which the primary object was the general improvement by ear-to-row selection of certain varieties of corn. Score card data were obtained for each ear used in the ear-to-row test, as well as the comparative yields of the progeny. (2) An experiment planned and carried out for the specific purpose of determining the relation between certain ear types and yield. As the two sources of data are unlike in nature the description of the methods and results of the two lines of experimental work will be given separately.

PART I. THE EAR-TO-ROW TEST

The ear-to-row test comprises data obtained at University Farm, Willmar, West Concord, and Cokato. The test at University Farm was by far the most extensive. Two varieties were used, Minnesota No. 13 and Minnesota No. 161. The tests at the other stations include the same varieties, and at Cokato an additional one, Minnesota No. 332.

The variety Minnesota No. 13 was originally obtained from a St. Paul seed company in 1893. It has been bred by the ear-to-row method since 1898, at University Farm. The breeding plot has been handled in the following way:

1. From the forty to seventy-five rows grown annually, the best ten to twenty were selected on a yield basis.

2. From each of these ten to twenty rows, from six to ten ears were selected from the field by inspection.

3. Since 1902 new blood has been introduced once by planting another selection of this variety in rows alternating with the breeding rows, which were detasseled.

4. The selected ears were scored and measured according to the following score card and scheme:

Maturity	25	Length of ear (inches)
Form of ear	20	Circumference (inches)
Variety character	15	Weight of ear (grams)
Tips	5	Weight of shelled corn (grams)
Butts	5	Percentage of shelled corn (by weight)
Kernel uniformity	10	
Percentage of corn to ear	20	
Total score	100	

5. The selected ears which received the highest total score were used in the ear-to-row work of each succeeding year.

The data concerning Minnesota No. 13 are for the years 1906 to 1914, inclusive, except 1908. Other years are omitted in some of the comparisons, as will be noted in the tables.

The variety Minnesota No. 161 was obtained from William Mulbrand, Le Sueur, in 1898. It was handled in the same way as Minnesota No. 13, except that no new blood was ever introduced. Data for Minnesota No. 161 are given for the years 1906 to 1913, inclusive, except 1908 and 1912. In some of the comparisons other years are omitted because of the incompleteness of the data for those years.

The variety Minnesota No. 332, which was used in the tests at Cokato, came from a selection made by Emil Titrud, of Cokato. It was handled in the same way as Minnesota No. 161 but for a shorter period, as were also the other tests carried on at the three outlying stations.

PRESENTATION OF DATA

Table I shows the general character of the data and the first step in the compilation. A description of each of the ears planted in 1911 is included, together with its yield in bushels per acre. The description is the score of each of the ears and its measurements according to the score card and scheme already described. Not all of the score-card points appear in the table, as all are not involved in the studies with which this bulletin deals. Thus ear No. 4705 has a total score of 74. Only 20 of this appears in the table. The other 54 points represent the total for maturity, form of ear, and shelling percentage (page 10).

A similar table is compiled for each year included in the test.

Relation of length of ear to yield.—Examination of the column for length of ear, in Table I, shows a range of variation of this character from 6.5 inches to 8.75 inches. On the basis of this variation, the ears have been separated into groups or classes, each group or class being represented by a part of the range covered by all of the ears. Table II illustrates this.

The forty-two ears included in Table I have been grouped into quarter-inch classes for length of ear in Table II. The yields of the progeny of those ears whose lengths fall in a particular class have been entered under the class heading in the table. Then averages were obtained for the yield of each class for length of ear, and the number of ears which appear in any particular class is recorded. This compilation is made for each year, and the averages thus obtained are brought together in Table III.

The final analysis of the data is given in Table III. Here all of the original classes are combined first into three groups, the "lower," "middle," and "upper" third, and then into two, the "lower" and "upper" half. This shows whether there is any relation between the character in question and yield. The grouping is brought about in the following way: Taking the 1911 figures again, for illustration, we find there are 42 ears represented. Each of the three classes, therefore, will consist of 14 ears. The 14 ears in the lower third class consist of the one ear in the 6.50 class, the two ears in the 7.00 class, the one ear in the 7.25 class, the nine ears in the 7.50 class, and one of the ten ears in the 7.75 class. The yield in each of these classes is multiplied by the number of ears in the class, the products added together, and the result divided by 14, thus:

$$\frac{(68.3\times1)+(65.0\times2)+(58.7\times1)+(62.3\times9)+(62.2\times1)=62.8}{14}$$

TABLE I

Typical Description of Ears Planted, Minnesota No. 161 Corn, 1911

Ear Number	Score					Length of ear	Circumference of ear	Weight of ear	Shelling percentage	Yield per acre
	Variety character	Tips	Butts	Kernel uniformity	Total					
						In.	In.	Gr.		Bu.
4705	11	1	2	6	74	7.50	6.25	233.8	84.1	59.3
4709	12	1	2	6	71	7.50	6.50	240.3	81.0	59.9
5108	13	4	2	7	85	7.75	6.00	231.3	81.1	65.1
5112	14	3	4	7	89	7.50	6.50	258.8	84.1	63.7
5307	11	3	2	6	73	6.50	6.00	198.9	79.4	68.3
5310	9	0	2	4	71	8.00	6.50	265.5	84.7	70.8
5312	13	3	3	7	85	8.00	6.75	286.6	81.8	67.1
5605	13	3	3	7	84	8.25	6.25	290.2	82.8	58.3
5607	12	0	3	6	77	7.50	6.25	234.0	85.4	63.1
5608	10	1	3	5	72	7.75	6.25	266.8	80.0	53.1
5610	13	2	4	7	85	7.75	6.25	254.2	84.6	64.2
5611	14	3	3	6	87	7.50	6.00	229.5	85.6	72.6
5612	12	0	2	6	80	7.00	6.25	226.7	86.1	62.1
5613	10	1	2	7	72	7.75	6.25	244.2	83.0	54.5
5708	12	1	3	6	80	8.25	6.50	259.6	82.5	66.5
5709	12	0	1	5	71	8.75	6.25	276.3	80.7	67.4
5710	13	2	2	6	83	8.00	5.75	234.3	85.7	63.2
5712	11	2	3	5	73	8.25	6.50	286.3	77.2	65.5
5713	12	2	3	6	77	8.00	6.50	262.7	84.4	53.9
5806	13	0	3	6	82	8.00	6.00	237.6	83.8	64.5
6305	12	2	2	7	83	7.00	6.75	256.9	84.9	67.8
6309	14	3	3	8	87	8.25	6.25	287.7	82.9	72.0
6708	11	3	3	6	79	7.50	6.25	240.7	82.4	64.3
7706	11	2	3	6	77	7.50	6.75	246.1	84.7	57.9
8005	12	3	3	6	82	8.75	6.25	279.4	85.1	63.8
8009	14	4	2	7	86	8.00	6.25	275.0	84.2	63.1
8106	13	2	4	7	83	8.00	6.25	262.1	82.3	75.4
8109	12	4	3	6	81	7.75	6.50	277.8	83.1	64.7
8705	12	1	2	6	77	7.50	7.00	299.6	83.0	68.7
8706	13	2	3	5	75	7.75	6.50	263.0	81.2	71.9
8708	13	2	4	7	81	7.75	6.75	264.1	81.5	65.5
8809	12	1	3	6	82	8.00	6.25	242.4	84.4	59.1
8813	11	4	3	6	81	7.25	6.50	250.0	82.5	58.7
8907	13	0	2	7	76	7.75	6.50	254.1	82.4	62.6
8909	13	3	4	7	83	7.75	6.25	258.1	81.7	54.0
8910	11	0	0	6	68	8.00	6.50	268.5	81.9	64.0
9007	12	4	3	7	78	8.25	6.50	292.3	79.5	61.7
9012	10	4	3	6	82	8.25	6.50	285.3	85.2	62.3
9107	13	0	3	6	82	7.75	6.25	251.2	83.8	66.5
9109	13	0	2	7	82	8.00	6.75	288.1	85.2	65.4
9308	13	2	3	8	85	7.50	6.50	259.4	84.7	52.2
9310	11	0	2	7	71	8.75	6.00	233.3	83.0	61.0

Table III shows that there is a slight progressive increase in yield from the lower to the upper third classes in the case of both Minnesota No. 13 and Minnesota No. 161. The difference in favor of the upper third over the lower third class is 0.8 bushel for Minnesota No. 13 and 1.2 bushels for Minnesota No. 161. In estimating the significance of this difference and of the progressive array of the final averages, other comparisons afforded by the table are of interest. We find, for instance, when we examine each of the six yearly results for Minnesota No. 13 that the lower third class leads in three years, the middle third in one, and the upper third in two. This apparently represents a mere chance array of the annual results. That is to say, the array is about the same as would be expected had each of the three groups represented a random selection of ears from a lot of corn. The deviation from such expectation is in the opposite direction from that indicated by the final averages.

TABLE II

Relation of Length of Ear to Yield, Minnesota No. 161—1911

	Length classes, inches									
	6.50	6.75	7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75
	Bu.	....	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	....	Bu.
	68.3	....	62.1	58.7	59.3	65.1	70.8	58.3	....	67.4
	....	....	67.8	....	59.9	53.1	67.1	66.5	....	63.8
	....	....	....	....	63.7	64.2	63.2	65.5	....	61.0
	....	....	....	....	63.1	54.5	53.9	72.0	....	....
	....	....	....	....	72.6	64.7	64.5	61.7	....	....
	....	....	....	....	64.3	71.9	63.1	62.3	....	....
	....	....	....	....	57.9	65.5	75.4	....	....	....
	....	....	....	....	68.7	62.6	59.1	....	....	....
	....	....	....	....	52.2	54.0	64.0	....	....	....
	....	....	....	....	....	66.5	65.4	....	....	....
Average	68.3	....	65.0	58.7	62.3	62.2	64.7	64.4	....	64.1
Number of ears	1	....	2	1	9	10	10	6	....	3

Applying the same analysis to Minnesota No. 161, the results are found to support the indication of direct or positive relation found in the final averages. The upper third class leads in three years and the middle class in the fourth year.

Another analysis of the data is afforded by a direct comparison of the original classes in the body of the table. Thus, for Minnesota No. 13 we have a six-year average for each class from 7.50 to 8.25, inclusive. This comparison shows a tendency toward a positive relation, the yield for the 7.75 class being the only exception. When the 1914 yields are excluded, however, so as to include one more class, the 7.25, in the comparison, little or no such tendency is exhibited. Similarly, when the comparable classes in the Minnesota No. 161 table are noted (classes 7.00 to 8.00 inclusive), no regular tendency, but mere fluctuation, is found to exist.

In the data from the outlying stations, Table IV, it is apparent at once that no relation is suggested. The average ears (middle third class) are found to lead in all cases except one, in which the middle and upper third classes are identical. Comparison of the upper and lower third classes, shows that each leads in two out of the four cases.

TABLE III

Relation of Length of Ear to Yield—University Farm

Year	Length classes, inches																						Lower third	Middle third	Upper third	Lower half	Upper half
	6.25		6.50		6.75		7.00		7.25		7.50		7.75		8.00		8.25		8.50		8.75						
	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.					
Minn. 13		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
1909......	1	63.0	1	64.5	..	....	6	63.9	8	66.6	12	65.2	7	68.5	5	68.0	1	66.0	..	....	..	....	65.0	65.4	67.9	65.1	67.1
1910......	..	....	..	....	..	....	..	....	5	44.5	12	47.2	7	45.5	11	44.7	2	50.7	2	46.3	..	....	46.2	45.9	45.9	46.1	45.9
1911......	..	....	..	....	3	50.6	4	54.0	8	53.8	10	57.7	8	58.5	3	55.4	2	58.4	..	....	..	....	53.1	56.8	57.7	54.5	57.5
1912......	..	....	1	55.0	2	45.1	8	46.9	6	45.5	9	45.8	5	40.7	7	46.1	3	46.6	3	47.8	..	....	46.8	44.7	45.8	46.0	45.5
1913......	..	....	1	57.9	3	71.9	3	67.4	4	70.0	16	68.1	4	68.2	2	69.0	1	62.2	2	63.9	..	....	68.7	68.1	67.1	68.6	67.4
1914......	..	....	..	....	..	....	..	....	..	....	4	64.7	12	66.1	8	67.4	5	69.5	5	61.1	1	61.2	65.6	66.8	65.2	66.0	65.7
Average	..	....	..	....	..	....	..	....	..	....	..	58.1	..	57.9	..	58.4	..	58.9	..	....	..	....	57.5	58.0	58.3	57.7	58.3
Av. all years except 1914	..	....	..	....	..	....	..	....	..	56.1	..	56.8	..	56.3	..	56.6	..	56.7	..	....	..	....	....	....	....	....	....
Minn. 161																											
1908......	..	....	..	....	..	....	4	68.8	5	67.3	7	63.3	9	65.6	14	66.8	3	63.8	6	73.0	1	63.3	65.9	66.1	68.3	66.0	68.0
1910......	..	....	..	....	1	46.7	5	49.3	10	50.4	6	50.9	8	46.4	14	48.4	4	57.1	2	47.6	..	....	49.9	48.2	50.4	49.3	49.7
1911......	..	....	1	68.3	..	....	2	65.0	1	57.8	9	62.3	10	62.2	10	64.7	6	64.4	..	....	3	64.1	62.8	63.1	64.4	62.9	64.0
1913......	..	....	..	....	5	71.3	4	67.1	5	72.1	9	70.2	9	70.6	1	66.7	..	....	..	....	..	....	69.9	70.7	70.2	70.2	70.4
Average	..	....	..	....	..	....	..	62.6	..	61.9	..	61.7	..	61.2	..	61.7	..	....	..	....	..	....	62.1	62.0	63.3	62.0	62.9

TABLE IV

Relation of Length of Ear to Yield—West Concord, Willmar, and Cokato

Variety and place	Year	Length classes, inches																								Lower third	Middle third	Upper third	Lower half	Upper half
		6.00		6.25		6.50		6.75		7.00		7.25		7.50		7.75		8.00		8.25		8.50		8.75						
		Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.					
			Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
Minn. 13																														
W. Concord ..	1910	1	21.4	1	21.4	2	40.4	1	30.2	6	30.4	3	33.6	11	34.0	2	35.8	1	31.5	1	27.7	..	....	..	....	30.6	33.5	33.5	31.3	33.6
W. Concord ..	1909	..	....	..	....	..	....	3	47.0	1	34.7	3	26.3	9	40.9	1	44.0	2	35.8	1	22.0	..	....	..	....	36.9	40.2	37.0	37.7	38.3
Average	....	..	....	..	....	..	....	..	38.6	..	32.6	..	30.0	..	38.0	..	39.9	..	33.7	..	24.9	..	....	..	....	33.8	36.9	35.3	34.5	35.9
Minn. 161																														
Willmar..	1906	..	....	..	....	..	....	..	....	..	....	..	....	1	47.2	6	49.9	7	43.3	1	32.4	4	39.4	4	33.5	47.8	41.6	36.3	47.0	37.0
Willmar..	1907	..	....	..	....	2	48.4	4	44.9	4	46.6	3	50.3	6	45.3	3	51.9	..	....	..	....	..	....	..	....	46.2	48.0	48.1	46.6	48.1
Willmar..	1908	1	60.7	1	59.2	4	61.7	1	60.0	4	64.3	3	72.3	4	57.9	1	72.1	..	....	..	....	..	....	..	....	61.0	66.0	63.2	61.8	65.0
Willmar..	1909	..	....	..	....	..	....	..	....	3	32.8	2	34.2	6	32.3	4	45.9	2	38.1	1	39.9	..	....	..	....	33.2	34.6	42.3	32.9	40.5
Average	....	..	....	..	....	..	....	..	....	..	....	..	....	..	45.7	..	55.0	..	....	..	....	..	....	..	....	47.1	47.5	47.5	47.1	47.8
Av. all years except 1906	....	..	....	..	....	..	....	..	....	..	47.9	..	52.3	..	45.2	..	56.6	..	....	..	....	..	....	..	....	....	....	....	....	....
Minn. 332																														
Cokato ..	1907	..	....	..	....	..	....	..	....	..	....	..	....	..	....	3	44.0	6	45.8	6	44.9	2	46.8	2	39.3	45.0	45.2	43.7	45.2	44.1
Cokato ..	1908	..	....	..	....	..	....	..	....	1	51.6	3	56.9	9	57.1	4	59.6	4	54.6	3	51.9	1	54.0	..	....	56.4	58.4	53.5	57.1	55.6
Average	....	..	....	..	....	..	....	..	....	..	....	..	....	..	....	..	51.8	..	50.2	..	48.4	..	50.4	..	....	50.7	51.8	48.6	51.4	49.9
Minn. 13																														
Cokato ..	1910	..	....	..	....	..	....	1	45.9	..	....	1	51.2	4	47.9	1	56.6	13	52.5	1	50.2	3	47.7	..	....	49.7	52.5	50.4	50.7	51.1
Cokato ..	1913	..	....	..	....	..	....	1	55.6	1	58.2	2	45.1	4	48.4	6	48.3	5	49.2	1	30.7	2	39.6	..	....	49.2	48.4	43.8	49.3	45.5
Average	....	..	....	..	....	..	....	..	50.8	..	....	..	48.2	..	48.2	..	52.5	..	50.9	..	40.5	..	43.7	..	....	49.5	50.5	47.1	50.0	48.3

The above data evidently offer no encouragement for selection emphasizing length in the hope of obtaining important increase in yield.

Relation of weight to yield.—Table V shows the advantage to be with the ears of average weight in the case of Minnesota No. 13. Not only is this true when the final averages are noted, but it is true for five of the six-year yields from which the averages are obtained. In the case of Minnesota No. 161, the advantage is with the heaviest ears, according to the final averages. But the yield of the lower third class exceeds that of the middle third class, by 0.2 bushel. The difference in favor of the upper third class over the lower third is 0.3 bushel. Obviously the advantage of the heaviest ears is of no significance. Further support for this conclusion is found when the results for each of the five years are examined. The heaviest class exceeds the lightest in only three out of the five years. When the three classes are compared, the heaviest class leads in two years, the middle in two, and the lowest in one year.

Results at the outlying stations are in substantial agreement with those for Minnesota No. 13 at University Farm (Table VI). The average ears (middle third class) lead at three out of the four stations. At the fourth, Willmar, yields of the lower and upper classes are identical and are in excess of the yield of the middle class.

The conclusion justified by these data is that any conscious selection for weight of ears should consist simply of elimination of extremes. In fact, one is probably safe in picking at random so far as weight is concerned.

Relation of shelling percentage to yield.—According to final averages for lower, middle, and upper third classes, Minnesota No. 13. University Farm (Table VII), the lower class is somewhat inferior to the other two, which are essentially identical. This would indicate no advantage in selecting seed ears of extremely high shelling percentage, but a slight advantage in eliminating those of very low shelling percentage. When the results for each of the six years are noted, however, the disadvantage of the lower class, while it still exists, is considerably reduced. The high rank of the upper class is largely due to the unusually high comparative yield for this class in 1914.

It is readily seen that the data for Minnesota No. 161 (Table VII) contradict those for Minnesota No. 13. They indicate a small advantage in favor of ears of lowest shelling percentage.

TABLE V

Relation of Weight of Ears to Yield—University Farm

Year	Weight classes, grams																				Lower third	Middle third	Upper third	Lower half	Upper half
	185		200		215		230		245		260		275		290		305		320						
	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld					
		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
Minn. 13																									
1909	..	....	4	66.0	16	65.5	12	67.5	7	65.6	2	65.0	..	....	..	....	..	....	..	....	65.6	66.6	66.1	65.9	66.3
1910	..	....	..	....	..	....	..	....	2	40.5	9	45.7	15	46.2	8	46.0	5	46.6	1	43.8	45.0	46.2	46.1	45.4	46.1
1911	..	....	3	50.3	3	51.7	9	54.7	19	58.0	5	55.6	..	....	..	....	..	....	..	....	53.0	57.5	57.2	54.5	57.3
1912	..	....	..	....	16	46.3	16	45.7	8	45.5	4	44.6	..	....	..	....	..	....	..	....	46.3	45.7	45.3	46.1	45.4
1913	..	....	2	64.5	15	68.2	8	69.2	4	63.3	3	69.9	1	70.2	..	....	..	....	..	....	67.5	68.7	67.3	67.9	67.8
1914	..	....	..	....	..	....	2	69.4	8	63.7	8	64.5	7	68.1	5	67.6	2	59.6	1	61.7	64.8	65.8	65.7	65.1	65.7
Average	..	....	..	....	..	....	..	....	..	56.1	..	57.6	..	....	..	....	..	....	..	....	57.0	58.4	57.9	57.5	58.1
Av. all years except 1910	..	....	..	....	..	....	..	61.3	..	59.2	..	59.9	..	....	..	....	..	....	..	....	....	....	....	....	....
Minn. 161																									
1909	10	66.0	22	66.6	11	67.1	4	69.9	1	72.1	..	....	..	....	1	56.2	..	....	..	....	66.2	66.6	67.4	66.3	67.1
1910	..	....	..	....	..	....	3	48.9	5	52.1	9	50.1	17	48.1	11	49.4	5	46.5	..	....	50.5	48.1	48.5	49.7	48.4
1911	..	....	1	68.3	..	....	7	63.7	8	60.7	13	63.2	5	64.6	7	64.6	1	68.7	..	....	62.7	62.8	64.8	62.7	64.1
1913	2	61.1	4	74.1	12	70.2	6	72.5	9	70.3	1	67.6	..	....	..	....	..	....	..	....	70.0	71.4	70.4	70.3	70.6
1906	..	....	..	....	19	62.0	9	62.2	3	61.4	5	60.7	1	66.8	..	....	..	....	..	....	62.0	62.1	61.8	62.0	62.0
Average	..	....	..	....	..	....	..	63.4	..	63.3	..	....	..	....	..	....	..	....	..	....	62.3	62.1	62.6	62.3	62.5

iety id ace	Year	Weight classes, grams																										Lower third	Middle third	Upper third	Lower half	Upper half
		125		140		155		170		185		200		215		230		245		260		275		290		305						
		Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.					
			Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
. 13 Con- d ...	1908	...	....	...	....	...	....	...	....	...	....	...	....	...	....	5	39.7	11	42.2	4	41.7	4	40.9	1	38.8	...	....	40.8	42.1	41.2	41.2	41.4
Con- d ...	1909	...	....	...	....	...	....	...	....	...	....	9	36.3	7	37.0	4	34.7	...	....	...	....	...	....	...	....	...	....	36.3	36.8	35.5	36.4	36.1
Con- d ...	1910	...	....	...	....	...	....	...	....	...	....	...	....	5	30.6	7	28.4	8	34.8	4	32.7	3	37.8	3	32.7	...	....	29.5	33.5	34.2	30.4	34.4
erage	....	...	....	...	....	...	....	...	....	...	....	...	....	...	....	...	....	...	....	...	....	...	....	...	....	...	....	35.5	37.5	37.0	36.0	37.3
. 161 nar...	1906	...	....	...	....	...	....	...	....	...	....	...	....	1	43.2	...	....	2	39.8	7	46.0	3	44.5	7	45.8	2	44.9	44.1	45.3	45.5	44.5	45.4
nar...	1907	...	....	3	45.8	6	47.0	8	47.2	2	45.4	3	51.7	...	....	...	....	...	....	...	....	...	....	...	....	...	....	46.6	47.2	48.6	46.7	48.1
nar...	1908	5	66.8	1	61.7	4	62.4	1	60.0	...	....	...	....	...	....	...	....	...	....	...	....	...	....	...	....	...	....	65.3	61.7	61.9	64.3	61.8
erage	....	...	....	...	....	...	....	...	....	...	....	...	....	...	....	...	....	...	....	...	....	...	....	...	....	...	....	52.0	51.4	52.0	51.8	51.8
. 332 to ...	1907	...	....	...	....	...	....	...	....	...	....	2	41.7	9	46.4	5	45.0	2	42.0	1	39.0	...	....	...	....	...	....	44.9	46.1	43.0	45.4	44.0
to ...	1908	...	....	...	....	...	....	...	....	...	....	11	54.8	7	57.8	6	56.9	1	54.0	...	....	...	....	...	....	...	....	54.8	56.8	56.7	55.2	57.1
verage	....	...	....	...	....	...	....	...	....	...	....	...	48.3	...	52.1	...	51.0	...	48.0	...	....	...	....	...	....	...	....	49.9	51.5	49.9	50.3	50.6
. 13 to ...	1910	...	....	...	....	...	....	...	....	...	....	1	45.9	...	....	1	49.6	3	52.6	3	48.5	10	51.7	5	52.1	1	43.8	49.9	51.7	51.0	50.4	51.2
to ...	1913	...	....	...	....	...	....	...	....	...	....	...	....	2	49.5	3	39.0	6	48.8	6	49.9	1	47.9	2	53.7	2	39.9	45.0	49.4	48.6	46.3	48.6
erage	....	...	....	...	....	...	....	...	....	...	....	...	....	...	....	...	44.3	...	50.7	...	49.2	...	49.8	...	52.9	...	41.9	47.5	50.6	49.8	48.3	49.9

TABLE VII

Relation of Shelling Percentage to Yield—University Farm

Year	Shelling percentage classes										Lower third	Middle third	Upper third	Lower half	Upper half
	78		81		84		87		90						
	Ears	Yield	Ears	Yield	Ears	Yield	Ears	Yield	Ears	Yield					
		Bu.		Bu.		Bu.		Bu.		Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
Minn. 13															
1909............	2	66.2	14	65.1	18	67.8	7	65.0	..	....	65.3	67.4	66.4	66.0	66.7
1910............	..	....	8	44.3	14	46.3	16	46.7	1	46.1	45.1	46.4	46.6	45.5	46.5
1911............	3	57.8	12	55.5	16	56.3	7	54.0	..	....	56.0	56.2	55.1	56.1	55.5
1912............	1	47.4	9	45.3	21	46.4	10	45.0	3	45.0	45.8	46.4	45.1	46.0	45.5
1913............	4	63.9	11	69.2	21	68.1	..	....	..	....	67.4	68.4	68.1	67.7	68.2
1914............	2	64.8	21	63.9	11	68.3	..	....	..	....	64.1	63.9	67.9	64.1	66.6
Average.......	..	....	..	52.6	..	57.2	..	....	..	....	57.3	58.1	58.2	57.6	58.1
Minn. 161															
1908............	6	66.3	17	68.7	19	66.8	7	63.6	..	....	67.8	67.6	65.5	67.7	66.2
1910............	1	50.8	3	49.4	25	48.2	21	49.9	..	....	48.6	48.7	49.9	48.7	49.5
1911............	2	66.9	13	64.0	24	63.2	3	65.7	..	....	64.4	63.2	63.7	64.0	63.5
1913............	4	73.8	11	70.0	19	70.1	..	....	..	....	71.4	70.1	70.1	71.0	70.1
Average.......	..	64.5	..	63.0	..	62.1	..	....	..	....	63.1	62.4	62.3	62.9	62.3

At the outlying stations (Table VIII) there is a slight indication of relation. The upper third class is exceeded by both middle and lower classes in three of the four tests. The lower class exceeds the middle by small margins at two of the three stations. Possibly a very slight inverse or negative relation exists.

Relation of circumference to yield.—While there is a constant increase on passing from upper to lower third class, in the case of Minnesota No. 13, University Farm (Table IX), suggesting an inverse or negative relation, the differences are so small as to be practically negligible. This is emphasized when upper and lower half classes are compared, the difference in favor of the latter being only 0.2 bushel.

In the case of Minnesota No. 161 (Table IX), the indication of negative correlation is even less. There is only 0.2 bushel in favor of lower third as compared with upper third class, and the middle class falls below both. When upper and lower half classes are compared, a difference of only 0.1 bushel in favor of the latter is found.

At the outlying stations practically all possible arrays of yields for the three classes are shown (Table X). At West Concord the upper class leads and the middle falls below both extremes. At Willmar the lower class leads, the middle again falling below both extremes. At Cokato a progressive increase in yield from lower to upper class is shown in the case of Minnesota No. 332. With Minnesota No. 13 the upper and middle classes are essentially identical, the middle class leading slightly, and the lower class falling below them.

Relation of butts to yield.—Minnesota No. 13 data indicate no relation of butts to yield, the three classes being essentially equal. In the case of Minnesota No. 161 the advantage is with the average ears. The lower third class leads the upper third by a margin of 0.6 bushel and the difference between upper and lower half is 0.4 bushel in favor of the latter. When the results for each of the original classes, 1.0 to 4.0 inclusive, are noted, mere fluctuation is apparent.

At each of the outlying stations the poorest butts show the highest yields (Table XII). Upper and middle third classes are very close in yield. Possibly slight negative correlation existed in these tests.

Relation of tips to yield.—The better tipped ears have a slight advantage in both Minnesota No. 13 and Minnesota No. 161. In Minnesota No. 13 differences are probably insignificant. This is emphasized by the fluctuation noted when the averages for each of the original classes are compared. With Minnesota No. 161, differences are somewhat greater altho still very small. The original classes show a progressive increase from lower to higher when the six-year averages are compared. The significance of this is greatly reduced, however, when the year 1906 is excluded so as to include class 0 in the comparison.

TABLE VIII

Relation of Shelling Percentage to Yield—West Concord, Willmar, and Cokato

Variety and place	Year	Shelling percentage classes										Lower third	Middle third	Upper third	Lower half	Upper half
		77		81		84		87		90						
		Ears	Yield	Ears	Yield	Ears	Yield	Ears	Yield	Ears	Yield					
			Bu.		Bu.		Bu.		Bu.		Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
Minn. 23																
West Concord	1908	1	44.3	7	40.6	14	41.3	3	41.6	..	....	41.1	41.3	41.4	41.1	41.4
West Concord	1909	..	....	9	38.8	10	36.5	1	46.3	..	....	38.8	37.2	38.1	38.6	37.5
West Concord	1910	4	32.7	12	33.4	10	31.8	3	30.4	..	....	33.1	32.8	31.3	33.2	31.7
Average	....	..	....	..	37.6	..	36.5	..	39.4	..	....	37.7	37.1	36.9	37.6	36.9
Minn. 161																
Willmar	1906	..	....	4	45.2	14	44.5	3	44.0	2	38.4	44.8	44.5	42.5	44.7	43.3
Willmar	1907	1	53.0	3	50.8	14	40.3	3	46.8	1	51.2	46.6	40.3	44.1	44.3	43.1
Willmar	1908	5	58.7	10	66.8	5	60.6	..	....	..	....	61.0	66.8	62.1	62.8	63.7
Willmar	1909	..	....	4	33.8	9	35.9	4	33.9	..	....	34.5	35.9	34.8	34.9	35.0
Average	....	..	....	..	49.2	..	45.3	..	....	..	....	46.7	46.9	45.8	46.7	46.3
Minn. 332																
Cokato	1907	..	....	4	47.7	10	45.2	4	43.6	..	....	46.9	45.2	44.1	46.3	44.5
Cokato	1908	5	57.1	10	58.3	10	53.4	..	....	..	....	57.6	57.7	53.4	57.8	54.4
Average	....	..	....	..	53.0	..	49.3	..	....	..	....	52.3	51.5	48.8	52.0	49.5
Minn. 13																
Cokato	1910	3	51.6	9	51.4	10	50.2	2	50.8	..	....	51.5	50.8	50.4	51.5	50.3
Cokato	1913	1	51.2	10	46.2	10	47.9	1	50.8	..	....	46.8	47.2	48.3	46.7	48.2
Average	....	..	51.4	..	48.8	..	49.1	..	50.8	..	....	49.2	48.9	49.4	49.1	49.3

TABLE IX

Relation of Circumference to Yield—University Farm

Year	Circumference classes, inches														Lower third	Middle third	Upper third	Lower half	Upper half
	5.50		5.75		6.00		6.25		6.50		6.75		7.00						
	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.					
		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
Minn. 13																			
1909	3	68.8	5	65.6	20	65.0	5	67.9	..	....	..	....	..	....	66.3	65.0	66.3	65.9	66.0
1910	..	....	..	....	13	47.1	11	42.1	14	45.2	2	45.5	..	....	47.1	42.6	45.2	45.6	44.3
1911	..	....	2	53.4	11	55.6	20	56.3	4	55.9	2	56.3	..	....	55.3	56.3	56.2	55.6	56.2
1912	..	....	1	39.6	4	41.7	16	47.1	17	45.2	5	49.6	1	39.4	45.2	46.0	46.3	45.5	46.2
1913	..	....	..	....	2	66.6	4	66.6	26	68.7	3	64.9	1	65.4	67.7	68.7	67.5	68.0	67.8
1914	..	....	1	58.0	2	67.1	5	65.6	17	67.7	9	62.1	..	....	65.8	67.7	63.5	66.4	64.9.
Average	..	....	..	....	..	57.2	..	57.6	..	....	..	....	..	....	57.9	57.7	57.5	57.8	57.6
Average all years except 1909	..	....	..	....	..	55.6	..	55.5	..	56.5	..	55.7	..	....	....	....	....	....	....
Minn. 161																			
1908	..	....	3	64.7	22	65.9	13	65.1	10	69.2	4	70.4	..	....	65.7	65.5	68.6	65.7	67.6
1910	..	....	..	....	9	51.0	13	49.0	15	48.6	9	47.4	4	50.9	50.1	48.7	48.5	49.7	48.6
1911	..	....	1	63.2	5	66.5	16	62.5	14	62.7	5	64.7	1	68.7	64.0	62.6	63.8	63.5	63.4
1913	..	....	..	....	4	68.4	7	73.8	14	69.7	5	69.8	4	70.3	71.8	69.7	69.9	71.1	69.9
Average	..	....	..	....	..	63.0	..	62.6	..	62.6	..	63.1	..	....	62.9	61.6	62.7	62.5	62.4

TABLE X

Relation of Circumference of Ear to Yield—West Concord, Willmar, and Cokato

Variety and place	Year	Circumference classes, inches														Lower third	Middle third	Upper third	Lower half	Upper half
		5.50		5.75		6.00		6.25		6.50		6.75		7.00						
		Ears	Yield	Ears	Yield	Ears	Yield	Ears	Yield	Ears	Yield	Ears	Yield	Ears	Yield					
			Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
Minn. 13																				
West Concord........	1909	..	....	3	37.3	2	41.6	13	39.4	..	....	2	45.2	..	....	39.1	39.4	41.1	39.2	40.6
West Concord........	1910	..	....	1	33.4	12	33.8	11	29.6	2	36.1	2	39.7	2	32.1	33.8	30.9	33.4	33.2	32.1
Average	....	..	....	..	35.4	..	37.7	..	34.5	..	....	..	42.5	..	....	36.5	35.2	37.2	36.2	36.4
Minn. 161																				
Willmar	1906	..	....	..	....	4	41.1	6	44.8	8	43.6	4	47.9	1	36.4	43.0	43.9	45.0	43.4	44.4
Willmar	1907	2	46.0	3	46.8	7	46.8	5	47.3	2	51.0	2	47.7	..	....	46.6	46.9	48.5	46.6	48.0
Willmar	1908	..	....	4	60.8	9	63.0	5	65.3	1	67.8	..	....	..	....	61.5	63.0	65.6	62.1	64.7
Willmar	1909	3	42.2	3	39.5	5	34.0	4	30.0	1	31.4	..	....	..	....	41.1	34.8	30.9	39.1	31.7
Average	....	..	....	..	....	..	46.2	..	46.8	..	48.5	..	....	..	....	48.1	47.2	47.5	47.8	47.2
Minn. 332																				
Cokato	1907	..	....	1	41.4	11	43.9	5	45.4	1	44.2	1	53.1	..	....	43.2	43.9	46.6	43.6	45.7
Cokato	1908	..	....	5	52.0	9	54.7	7	59.5	4	58.5	..	....	..	....	53.0	55.9	59.1	53.6	58.6
Average	....	..	....	..	46.7	..	49.3	..	52.5	..	51.4	..	....	..	....	48.1	49.9	52.9	48.6	52.1
Minn. 13																				
Cokato	1910	..	....	1	45.9	5	51.3	5	53.9	3	48.8	4	51.7	1	52.3	50.7	53.1	51.2	51.7	51.2
Cokato	1913	..	....	..	....	..	....	6	45.2	2	46.3	12	48.7	2	52.5	45.4	48.4	50.0	46.4	49.5
Average	....	..	....	..	....	..	....	..	49.6	..	47.6	..	50.2	..	52.4	48.1	50.8	50.6	49.0	50.4

TABLE XI

RELATION OF BUTTS TO YIELD—UNIVERSITY FARM

Year	Butt score classes, based on 5 as a perfect score												Lower third	Middle third	Upper third	Lower half	Upper half
	0		1.0		2.0		3.0		4.0		5.0						
	Ears	Yield	Ears	Yield	Ears	Yield	Ears	Yield	Ears	Yield	Ears	Yield					
		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
Minn. 13																	
1906	..	....	..	....	2	54.9	3	59.7	31	62.6	6	59.9	60.9	62.6	61.4	61.5	61.8
1907	..	....	..	....	..	....	24	50.6	8	50.3	1	56.7	50.6	50.6	50.9	50.6	50.8
1909	..	....	1	65.9	11	65.4	16	67.0	13	65.6	..	....	65.6	67.0	65.6	66.1	66.1
1910	..	....	1	44.0	7	48.7	26	46.0	6	43.5	..	....	47.3	46.0	44.9	46.9	45.3
1911	..	....	..	....	2	55.1	22	56.0	5	56.5	..	....	55.8	56.0	56.3	55.9	56.2
1912	..	....	2	42.9	12	47.4	21	45.0	9	46.0	..	....	46.6	45.0	45.6	46.1	45.4
1913	..	....	1	65.4	3	65.6	16	68.7	14	66.3	2	73.0	67.7	67.9	67.4	67.8	67.6
1914	..	....	..	....	..	....	3	63.2	18	65.8	12	66.2	65.1	65.8	66.2	65.3	66.1
Average	..	....	..	....	..	....	..	57.0	..	57.1	..	....	57.5	57.6	57.4	57.5	57.4
Minn. 161																	
1906	..	....	1	66.8	7	63.8	17	61.7	12	61.0	..	....	63.3	61.7	61.0	62.8	61.3
1909	..	....	10	66.2	28	68.6	9	65.0	2	56.7	..	....	67.1	68.6	65.3	67.6	66.0
1910	..	....	6	46.1	17	49.0	24	49.9	3	47.1	..	....	48.0	49.6	49.4	48.5	49.5
1911	..	....	1	67.4	14	63.7	21	62.8	5	64.5	..	....	64.0	62.9	63.5	63.7	63.3
1913	..	....	1	58.4	8	70.0	9	74.3	14	69.6	2	66.8	69.7	72.4	69.1	70.6	70.2
1907	4	61.4	5	66.2	12	62.0	14	63.1	4	64.1	..	....	63.4	62.4	63.4	63.1	63.1
Average	..	....	..	61.9	..	62.9	..	62.8	..	60.5	..	....	62.6	62.9	62.0	62.7	62.3

TABLE XII

Relation of Butts to Yield—West Concord, Willmar, and Cokato

Variety and place	Year	Butt score classes, based on 5 as a perfect score																		Lower third	Middle third	Upper third	Lower half	Upper half
		0.5		1.0		1.5		2.0		2.5		3.0		3.5		4.0		4.5						
		Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.					
			Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
Minn. 13																								
West Concord....	1908	..	....	3	37.0	13	28.9	9	32.2	4	31.5	..	....	..	....	..	....	..	....	31.3	30.0	31.9	30.6	31.7
West Concord....	1909	..	....	1	37.0	1	35.8	9	37.9	3	37.2	1	34.1	..	....	..	....	..	....	37.3	37.9	36.7	37.5	37.1
West Concord....	1910	..	....	..	....	..	....	7	44.3	9	39.8	6	41.8	2	38.9	1	35.2	..	....	43.7	40.0	40.1	42.3	40.2
Average........	....	..	....	..	....	..	....	..	38.1	..	36.2	..	....	..	....	..	....	..	....	37.4	36.0	36.2	36.8	36.3
Minn. 161																								
Willmar	1907	..	....	..	....	..	....	..	....	..	....	2	45.4	12	47.6	8	46.9	1	51.2	47.1	47.5	47.5	47.2	47.4
Willmar	1908	..	....	..	....	..	....	..	....	..	....	..	....	9	64.7	10	62.4	..	....	64.7	63.4	62.4	64.6	62.4
Willmar	1909	1	24.3	..	....	..	....	3	35.9	7	35.4	5	36.0	3	34.4	..	....	..	....	35.7	35.6	35.2	34.4	35.4
Average........	....	..	....	..	....	..	....	..	....	..	....	..	....	..	....	..	....	..	....	49.2	48.8	48.4	48.7	48.4
Minn. 332																								
Cokato	1907	..	....	..	....	..	....	..	....	..	....	..	....	..	....	8	47.0	11	42.9	47.0	44.0	42.9	46.3	42.9
Cokato	1908	..	....	..	....	..	....	..	....	..	....	10	55.0	14	56.9	1	55.8	..	....	55.0	56.4	56.8	55.4	56.8
Average........	....	..	....	..	....	..	....	..	....	..	....	..	....	..	....	..	....	..	....	51.0	50.2	49.9	50.9	49.9
Minn. 13																								
Cokato	1910	..	....	..	....	2	53.4	6	49.3	3	54.2	8	51.3	5	49.4	..	....	..	....	50.5	52.4	50.1	51.4	50.5
Cokato	1911	..	....	5	52.6	0	44.3	7	48.8	1	40.2	..	....	..	....	..	....	..	....	50.0	44.8	47.7	48.1	46.8

TABLE XIII

Relation of Tips to Yield—University Farm

Year	Tip score classes, based on 5 as a perfect score												Lower third	Middle third	Upper third	Lower half	Upper half
	0		1.0		2.0		3.0		4.0		5.0						
	Ears	Yield	Ears	Yield	Ears	Yield	Ears	Yield	Ears	Yield	Ears	Yield					
		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
Minn. 13																	
1906	..	....	..	....	4	61.8	11	63.0	19	62.0	8	59.1	62.7	62.1	60.3	63.4	61.0
1907	7	50.3	2	47.4	16	50.9	13	50.4	2	46.1	..	....	50.0	50.8	49.8	50.0	50.1
1909	14	65.7	..	....	16	66.3	6	66.4	4	67.0	1	63.2	65.7	66.3	66.3	65.9	66.4
1910	5	46.2	..	....	18	45.5	12	46.7	4	47.3	2	43.7	45.8	45.9	46.4	45.5	46.6
1911	5	55.4	..	....	8	55.6	15	56.7	7	55.4	3	57.6	55.5	56.7	56.3	55.6	56.1
1912	12	46.5	2	41.4	14	45.5	11	46.1	5	46.2	..	....	45.8	45.6	46.1	45.7	45.9
1913	7	68.8	2	72.0	5	67.1	9	68.2	9	66.2	4	69.0	68.9	67.9	67.1	68.5	67.3
1914	13	63.3	3	62.3	8	69.1	6	66.6	2	67.9	1	70.7	63.3	66.2	67.7	64.2	67.2
Average	..	....	..	....	..	57.7	..	58.0	..	57.3	..	....	57.2	57.7	57.5	57.4	57.6
Average all years except 1906	..	56.5	..	....	..	57.3	..	57.3	..	56.6	..	....	....	....	....	....	....
Minn. 161																	
1906	..	....	..	....	7	62.1	17	61.9	10	62.5	3	62.1	62.0	61.9	62.4	62.0	62.3
1907	9	62.2	..	....	7	63.6	18	62.8	3	63.6	1	67.0	62.6	63.0	63.4	62.7	63.3
1909	17	67.5	11	67.3	15	65.9	3	67.2	2	66.6	1	60.6	67.5	67.0	65.9	67.3	66.3
1910	10	45.2	5	47.0	19	50.9	13	49.5	3	49.8	..	....	46.4	50.9	49.6	47.9	50.1
1911	10	64.7	8	60.4	10	63.7	9	64.9	6	62.6	..	....	63.5	62.8	64.0	63.3	63.6
1913	14	71.7	..	....	4	65.9	5	67.3	5	74.8	6	69.8	71.7	68.0	72.1	70.5	70.7
Average	..	....	..	....	..	62.0	..	62.3	..	63.3	..	....	62.3	62.3	62.9	62.3	62.7
Average all years except 1906	..	62.3	..	....	..	62.0	..	62.4	..	63.4	..	....	....	....	....	....	....

TABLE XIV

Relation of Tips to Yield—West Concord, Willmar, and Cokato

Variety and place	Year	Tip score classes, based on 5 as a perfect score																						Lower third	Middle third	Upper third	Lower half	Upper half
		0		0.5		1.0		1.5		2.0		2.5		3.0		3.5		4.0		4.5		5.0						
		Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.					
			Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
Minn. 13																												
W. Concord..	1908	9	41.5	1	45.7	2	42.9	8	42.4	4	37.9	1	35.2	..	....	..	....	..	....	..	....	..	....	41.5	42.7	39.3	42.1	40.4
W. Concord..	1909	..	....	5	37.5	6	36.6	5	41.3	3	41.1	..	....	1	23.1	..	....	..	....	..	....	..	....	37.2	38.2	41.2	37.1	39.0
W. Concord..	1910	13	31.4	7	34.9	7	32.8	3	31.5	..	....	..	....	..	....	..	....	..	....	..	....	..	....	31.4	33.9	32.4	31.9	33.2
Average ...	....	..	....	..	39.4	..	37.4	..	38.4	..	....	..	....	..	...	..	....	..	....	..	....	..	....	36.7	38.3	37.6	37.0	37.2
Minn. 161																												
Willmar	1907	..	....	..	....	..	....	..	....	..	....	..	....	2	47.7	10	46.4	7	48.5	3	47.7	..	....	46.7	46.4	48.1	46.6	48.1
Willmar	1908	..	....	..	....	..	....	..	....	..	....	..	....	1	64.1	11	59.3	7	61.9	..	....	..	....	60.0	59.7	61.9	59.8	61.2
Willmar	1909	1	27.5	2	28.8	2	31.4	1	34.7	5	40.4	1	38.1	2	37.1	1	32.3	..	....	..	....	..	....	29.6	39.3	37.0	32.4	38.2
Average ...	....	..	....	..	....	..	....	..	....	..	....	..	....	..	49.6	..	46.0	..	....	..	....	..	....	45.4	48.5	48.8	46.3	49.2
Minn. 332																												
Cokato	1907	..	....	..	....	..	....	..	....	..	....	..	....	..	....	..	....	5	46.9	13	47.4	1	44.2	47.0	47.4	46.9	47.1	46.0
Cokato	1908	..	....	..	....	..	....	..	....	..	....	6	54.5	16	56.5	3	57.2	..	....	..	....	..	....	55.2	56.5	56.8	55.5	56.7
Average ...	....	..	....	..	....	..	....	..	....	..	....	..	....	..	....	..	....	..	....	..	....	..	....	51.1	52.0	51.9	51.3	51.4
Minn. 13																												
Cokato	1910	6	50.5	..	....	2	54.4	..	....	8	50.7	3	50.2	3	48.4	1	51.2	1	56.6	..	....	..	....	51.5	50.7	50.4	51.2	50.5
Cokato	1913	1	54.2	1	30.7	11	48.3	7	46.4	2	50.8	..	....	..	....	..	....	..	....	..	....	..	....	46.8	47.8	47.8	47.2	47.5

At the outlying stations, grouping into upper, lower, and middle third classes seems to indicate some positive correlation. Yields of upper and lower third classes, which are rather close, are considerably in excess of those of the lower class at three of the four places. Upon grouping into lower and upper half classes, however, no indication of relation is found. There is a distinct difference between the two classes in only one of the four cases, when the upper half leads. In the remaining three the yields are essentially identical. There is one plus difference of 0.2 and another of 0.1 bushel. There is one minus difference of 0.2 bushel. Mere chance array of the data in the various classes is apparently operating to a large degree in bringing about the differences between the final averages.

Relation of kernel uniformity to yield.—Table XV indicates no relation between kernel uniformity and yield. Minnesota No. 13 shows upper third class leading middle and lower classes, which are essentially identical. But when results for each year are noted, the lower and upper classes each lead in three years and the middle class in two. When upper and lower half classes are compared, each leads in four out of the eight years.

In the case of Minnesota No. 161, the upper class is outyielded by the middle and lower classes, which are again essentially identical. When each year is considered separately the same tendency is shown. Possibly a slight negative relation exists altho it is rendered doubtful by the Minnesota No. 13 results.

At the outlying stations the lower third class leads in all of the four cases (Table XVI). In one, however, the difference in favor of the lower third class is only 0.2 bushel. Furthermore, in this instance the middle class is considerably below both extremes, indicating no relation. Possibly some negative relation exists.

Relation of variety character to yield.—Final averages for Minnesota No. 13 show a small progressive increase from lower to upper class. Differences between lower and upper third classes are 0.8 bushel and between lower and upper half classes 0.5 bushel in favor of upper class. When the distribution of the yearly yields of these classes is noted, it is found that positive relation is indicated in, at most, five of the eight years.

In the case of Minnesota No. 161, the averages are clearly mere fluctuations. While upper third class leads lower third, the excess is practically no greater than that of middle third class over upper third. There is no agreement between the three years in the test as regards the arrays in the final classes. Furthermore, the averages of the original classes show no definite tendency.

TABLE XV

Relation of Kernel Uniformity to Yield—University Farm

Year	Kernel uniformity score classes, based on 10 as a perfect score																Lower third	Middle third	Upper third	Lower half	Upper half
	2.0		3.0		4.0		5.0		6.0		7.0		8.0		9.0						
	Ears	Yield	Ears	Yield	Ears	Yield	Ears	Yield	Ears	Yield	Ears	Yield	Ears	Yield	Ears	Yield					
		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
Minn. 13																					
1906	..	....	..	....	1	65.4	3	64.1	11	61.3	7	58.7	16	60.5	5	63.2	62.2	59.7	61.4	61.3	60.8
1907	..	....	..	....	..	....	2	52.4	8	51.6	11	48.4	18	49.9	5	51.9	50.8	49.3	50.6	50.3	50.1
1909	..	....	..	....	..	....	7	63.2	15	65.9	15	67.5	4	66.6	..	....	64.7	66.4	67.1	65.3	66.9
1910	..	....	..	....	1	44.6	12	45.8	15	45.8	7	44.7	5	45.6	..	....	45.6	45.8	45.2	45.5	45.2
1911	..	....	..	....	..	....	..	....	2	56.0	18	55.2	18	56.5	..	....	55.3	55.8	56.5	55.4	56.3
1912	..	....	..	....	..	....	6	45.7	6	44.3	19	46.9	4	46.5	..	....	45.0	46.9	46.8	45.6	46.8
1913	..	....	..	....	..	....	1	65.2	..	....	21	67.4	13	68.9	1	71.4	67.2	67.8	69.0	67.4	68.6
1914	..	....	..	....	..	....	..	....	1	61.8	11	67.1	21	65.1	..	....	66.6	65.3	65.1	66.1	65.1
Average	..	....	..	....	..	....	..	....	..	....	..	57.0	..	57.5	..	....	57.2	57.1	57.7	57.2	57.5
Minn. 161																					
1906	1	68.3	17	62.5	17	61.3	2	59.2	..	....	..	....	..	....	..	....	63.0	61.9	61.0	62.7	61.3
1907	10	63.2	22	62.4	6	64.9	..	....	..	....	..	....	..	....	..	....	63.0	62.4	63.7	62.8	63.3
1909	..	....	1	63.8	1	69.9	9	65.6	21	67.4	15	65.2	1	72.5	..	....	66.3	67.4	65.7	66.7	66.3
1911	..	....	..	....	1	70.8	4	64.5	20	63.2	15	63.3	2	62.1	..	....	64.1	63.3	63.1	63.9	63.2
1913	..	....	..	....	..	....	..	....	2	66.4	11	70.2	18	71.3	3	69.3	69.5	71.1	70.8	70.1	70.9
1910	..	....	1	49.7	5	48.8	5	48.9	21	50.4	16	47.4	2	48.7	..	....	49.4	50.0	47.6	49.6	48.4
Average	..	....	..	....	..	....	..	....	..	61.9	..	61.5	..	63.7	..	....	62.6	62.7	62.0	62.6	62.2

TABLE XVI

Relation of Kernel Uniformity to Yield—West Concord, Willmar, and Cokato

Variety and place	Year	Kernel uniformity score classes, based on 10 as a perfect score																								Lower third	Middle third	Upper third	Lower half	Upper half
		2.0		2.5		3.0		3.5		4.0		4.5		5.5		6.0		6.5		7.0		7.5		8.0						
		Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.					
			Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
Minn. 13																														
W. Concord ...	1908	2	41.4	7	40.3	9	42.1	5	39.7	1	42.8	1	45.7	...	....	...	....	...	....	...	....	...	....	...	....	40.5	42.1	41.1	41.0	41.5
W. Concord ...	1909	...	....	...	....	1	35.8	9	41.3	8	40.7	3	38.4	...	....	...	....	...	....	...	....	...	....	...	....	40.5	41.0	39.7	40.7	40.1
W. Concord ...	1910	...	....	...	....	...	....	...	....	...	....	...	....	1	30.2	6	35.3	3	34.6	6	30.4	4	34.6	9	30.5	34.5	32.1	30.5	33.3	31.6
Average	....	...	....	...	....	...	39.0	...	40.5	...	41.8	...	42.1	...	....	...	....	...	....	...	....	...	....	...	....	38.5	38.4	37.1	38.3	37.8
Minn. 161																														
Willmar...	1907	...	....	...	....	1	53.0	4	43.2	8	46.6	9	49.3	...	....	...	....	...	....	...	....	...	....	...	....	45.7	47.4	49.3	45.9	48.8
Willmar...	1908	...	....	...	....	...	....	1	64.7	8	67.5	10	60.1	...	....	...	....	...	....	...	....	...	....	...	....	67.1	62.6	60.1	66.8	60.1
Willmar...	1909	...	....	...	....	3	32.4	7	36.2	6	33.6	...	....	...	....	...	....	...	....	...	....	...	....	...	....	34.3	35.7	33.6	34.8	34.3
Average	....	...	....	...	....	...	....	...	48.0	...	49.2	...	....	...	....	...	....	...	....	...	....	...	....	...	....	49.0	48.6	47.7	49.2	47.7
Minn. 332																														
Cokato ...	1907	...	....	...	....	...	....	...	....	14	45.3	5	43.1	...	....	...	....	...	....	...	....	...	....	...	....	45.3	45.3	43.5	45.3	44.1
Cokato ...	1908	...	....	...	....	...	....	4	58.1	16	55.5	5	56.6	...	....	...	....	...	....	...	....	...	....	...	....	56.7	55.5	56.2	56.3	55.9
Average	....	...	....	...	....	...	....	...	....	...	50.4	...	49.9	...	....	...	....	...	....	...	....	...	....	...	....	51.0	50.4	49.9	50.8	50.0
Minn. 13																														
Cokato ...	1910	...	....	...	....	...	....	...	....	...	....	...	....	...	....	3	52.3	2	51.2	7	52.6	1	49.1	11	49.5	52.1	51.0	49.5	52.3	49.5
Cokato ...	1913	...	....	...	....	...	....	...	....	...	....	...	....	...	....	5	51.2	...	....	6	40.4	...	....	11	49.5	47.2	45.6	49.5	45.3	49.5
Average	....	...	....	...	....	...	....	...	....	...	....	...	....	...	....	...	51.8	...	....	...	46.5	...	....	...	49.5	49.7	48.3	49.5	48.8	49.5

TABLE XVII

RELATION OF VARIETY CHARACTER TO YIELD—UNIVERSITY FARM

Year	Variety character score classes, based on 15 as a perfect score																						Lower third	Middle third	Upper third	Lower half	Upper half
	5.0		6.0		7.0		8.0		9.0		10.0		11.0		12.0		13.0		14.0		15.0						
	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.	Ear	Yld.	Ear	Yld.	Ears	Yld.	Ears	Yld.	Ears	Yld.					
Minn. 13		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
1906......	..	....	5	59.5	7	64.6	17	62.2	12	60.7	1	59.5	..	....	..	....	..	....	..	....	..	....	62.4	62.2	60.7	62.3	61.2
1907......	..	....	1	50.7	12	49.4	23	50.5	3	49.5	1	55.4	..	....	..	....	..	....	..	....	..	....	49.5	50.5	50.6	49.8	50.5
1909......	3	67.6	9	65.0	14	64.6	15	67.8	..	....	..	....	..	....	..	....	..	....	..	....	..	....	65.5	64.8	67.8	65.3	66.9
1910......	..	....	..	....	..	....	..	....	1	41.2	10	47.1	1	46.1	18	45.3	2	48.6	8	46.3	..	....	46.4	45.3	46.3	46.1	46.0
1911......	..	....	..	....	..	....	..	....	..	....	2	56.9	..	....	11	55.4	11	49.0	15	56.6	9	58.0	55.6	55.9	57.7	55.8	57.2
1912......	..	....	..	....	..	....	..	....	3	44.3	2	42.6	7	45.6	22	46.1	7	46.5	1	44.2	..	....	45.2	46.1	46.0	45.6	46.0
1913......	..	....	..	....	..	....	..	....	..	....	1	66.4	9	66.8	18	69.2	7	65.9	..	....	..	....	67.2	69.2	67.1	67.9	67.8
1914......	..	....	..	....	..	....	..	....	..	....	..	....	2	62.0	5	66.3	17	65.1	9	67.4	..	....	65.1	65.1	67.0	65.1	66.4
Average	..	....	..	....	..	....	..	....	..	....	..	....	..	....	..	56.5	..	55.0	..	....	..	....	57.1	57.4	57.9	57.2	57.7
Minn. 161																											
1910......	..	....	1	45.0	..	....	10	49.3	6	51.5	5	54.4	11	49.6	15	49.0	2	49.6	..	....	..	....	50.0	51.0	49.1	50.3	49.7
1911......	..	....	..	....	..	....	..	....	1	70.8	3	56.6	8	63.2	12	63.2	14	63.9	4	67.8	..	....	62.3	63.4	65.0	62.7	64.5
1913......	..	....	..	....	..	....	..	....	2	66.4	1	63.7	9	71.2	14	71.2	7	70.8	1	56.8	..	....	69.6	71.2	69.8	70.1	70.3
Average	..	....	..	....	..	....	..	....	..	62.0	..	58.2	..	61.3	..	61.1	..	61.4	..	....	..	....	60.6	61.9	61.3	61.0	61.5

TABLE XVIII

RELATION OF MATURITY TO YIELD—UNIVERSITY FARM

Year	Maturity score classes, based on 25 as a perfect score																Lower third	Middle third	Upper third	Lower half	Upper half
	18		19		20		21		22		23		24		25						
	Ears	Yield	Ears	Yield	Ears	Yield	Ears	Yield	Ears	Yield	Ears	Yield	Ears	Yield	Ears	Yield					
		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
Minn. 13																					
1910	2	48.0	..	....	9	45.6	..	....	17	46.3	..	....	8	46.1	4	43.7	46.2	46.3	45.5	46.3	45.8
1911	..	....	..	....	6	53.4	..	....	26	56.3	..	....	6	56.6	..	....	54.9	56.3	56.5	55.4	56.5
1912	..	....	..	....	..	....	..	....	6	47.2	8	46.7	1	49.4	29	45.2	47.0	45.2	45.2	46.4	45.2
1913	..	....	..	....	..	....	1	64.7	2	68.0	3	64.3	6	69.7	24	68.2	67.6	68.2	68.2	67.8	68.2
1914	..	....	..	....	2	62.2	1	69.5	4	62.8	11	66.6	3	70.9	12	64.8	64.7	67.6	64.8	65.7	65.7
Average	..	....	..	....	..	....	..	....	..	56.1	..	....	..	58.5	..	....	56.1	56.7	56.0	56.3	56.3
Minn. 161																					
1910	..	....	..	....	2	48.5	..	....	12	50.3	8	45.5	1	45.2	27	49.7	49.2	48.2	49.7	48.9	49.2
1911	2	59.6	3	57.2	4	63.7	..	....	12	63.3	7	64.4	3	68.5	10	63.8	61.4	63.8	64.8	62.2	64.5
1913	..	....	..	....	..	....	1	68.1	1	58.4	7	73.5	1	74.4	21	69.3	71.5	69.3	69.3	70.8	69.3
Average	..	....	..	....	..	....	..	....	..	57.3	..	61.1	..	62.7	..	60.9	60.7	60.4	61.3	60.6	61.0

Relation of maturity to yield.—It is apparent at once that no relation between maturity and yield is indicated. These data, however, do not constitute any real test of the question, or at least this method of analysis does not, because of the high degree of maturity of practically all of the ears. It will be noted that in only two out of the eight individual year tests do any considerable proportion of the ears used fall below the 22 class for maturity.

Another comparison which to some extent explains the lack of correlation between maturity and yield is that of the few extremely low ears with those of average maturity. In Table XIX, the ears falling below 21 are compared with those above this score.

TABLE XIX

COMPARATIVE YIELDS OF EARS OF RELATIVELY LOW AND HIGH MATURITY

Variety	Year	Yield for ears scoring 21 and lower		Yield for ears scoring above 21	
		Tests	Average yield	Tests	Average yield
			Bu.		Bu.
Minnesota 13...........	1910	11	46.0	19	45.9
Minnesota 13...........	1911	6	53.4	32	56.4
Minnesota 13...........	1913	1	64.7	35	68.1
Minnesota 13...........	1914	3	64.6	30	65.8
Minnesota 161..........	1910	2	48.5	48	49.1
Minnesota 161..........	1911	9	60.7	32	64.1
Minnesota 161..........	1912	1	68.1	30	70.2

While this comparison can not be regarded as entirely trustworthy, owing to the small number of ears in the lower extreme class in most cases, the fact that the ears scoring above 21 outyielded those falling below this in six out of seven cases is significant. It is indicated that the ears of lower maturity, even tho carefully cured as were these ears, will not give as high yields as those more nearly mature.

Relation of total score to yield.—The relation of total score to yield obviously is the final criterion of the validity of the score card as an index to yield, so far as the present data are concerned. Those ears which approach the perfect standard with respect to every character in the score card are compared with reference to yield with those which possess these characters in a less degree. The range between poorer and better ears is considerable, as reference to Table XX shows. The extreme range is over 28, altho most of the ears are included within the range of about 68-88. University Farm data only are available for this study.

TABLE XX

Relation of Total Score to Yield—University Farm

Year	Total score classes, based on 100 as a perfect score																		Lower third	Middle third	Upper third	Lower half	Upper half
	66.0		69.5		73.0		76.5		80.0		83.5		87.0		90.5		94.0						
	Ears	Yield	Ears	Yield	Ears	Yield	Ears	Yield	Ears	Yield	Ears	Yield	Ears	Yield	Ears	Yield	Ears	Yield					
		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.		Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
Minn. 13																							
1906	1	51.8	1	64.8	2	65.0	7	62.3	8	61.3	11	63.1	7	60.0	4	62.2	..	....	61.9	62.5	61.2	62.1	62.4
1907	2	50.5	8	50.7	10	49.7	8	47.7	2	53.5	5	53.5	3	50.4	1	56.2	..	....	50.4	48.8	52.1	49.9	51.0
1909	1	65.9	4	65.8	7	63.7	12	67.9	10	66.5	3	62.8	2	69.5	..	....	..	....	65.6	67.7	66.1	66.5	66.7
1910	3	46.8	3	48.1	11	45.6	10	45.9	4	45.7	8	46.1	1	43.9	..	....	..	....	46.5	45.8	45.8	46.3	45.8
1911	..	....	3	55.2	1	62.7	10	54.3	8	55.2	14	57.3	2	54.4	..	....	..	....	55.2	55.8	56.8	55.3	56.5
1912	..	....	2	44.9	3	43.6	5	45.0	13	46.3	15	46.3	3	49.0	3	42.0	..	....	45.1	46.3	46.0	45.5	46.1
1913	..	....	1	62.7	1	65.5	2	64.1	5	68.5	18	68.8	5	68.1	3	66.0	..	....	67.1	68.8	67.7	67.7	68.1
1914	..	....	..	....	..	....	..	....	3	61.7	10	64.3	14	66.4	5	67.3	1	74.0	63.6	66.0	67.5	64.4	67.0
Average	..	....	..	....	..	....	..	....	...	57.3	..	57.8	..	57.7	..	....	..	....	56.9	57.7	57.9	57.2	57.9
Average all years except 1914	..	....	..	56.0	..	56.5	..	55.3	..	56.7	..	56.9	..	56.5	..	....	..	....	....	....	....	....	....
Minn. 161																							
1911	..	....	5	64.6	5	60.1	7	62.8	6	63.6	15	62.3	3	69.2	1	63.7	..	....	62.5	63.0	63.9	62.6	63.6
1910	..	....	8	46.8	5	51.9	13	47.9	13	46.5	8	50.6	2	49.7	1	47.7	..	....	48.6	47.2	48.9	48.1	48.0
1913	..	....	2	64.2	2	67.1	3	69.7	9	70.8	4	72.5	8	73.5	5	70.6	1	56.8	68.6	71.9	70.9	69.7	71.5
Average	..	....	..	58.5	..	59.7	..	60.1	..	60.3	..	61.8	..	64.1	..	60.7	..	....	59.9	60.7	61.2	60.1	61.0

Some correlation is indicated by the data for both Minnesota No. 13 and Minnesota No. 161. The differences between the upper and lower classes, however, are small. Minnesota No. 13 shows a difference of 1 bushel in favor of the upper third over the lower third class. Between upper half and lower half classes the difference is only 0.7 bushel. Corresponding differences in the case of Minnesota No. 161 are respectively 1.3 bushels and 0.9 bushel. Examination of the results for each of the eight years reveals that in case of Minnesota No. 13 there is a regular increase from the lower to the upper class in two out of eight years. For the other six years the upper third class surpasses the lower in four years. In one of these four years the middle class falls below both extremes, indicating no correlation. To put the matter more concretely, in two out of the eight years positive correlation is definitely shown; in three years positive correlation is indicated, upper third yielding more than lower third, but both being exceeded by middle third; during the remaining three years either negative correlation or no correlation is indicated.

Comparison of the original classes, for six of which there are seven-year averages, shows a good deal of fluctuation, altho a positive tendency is indicated.

In the case of Minnesota No. 161 definite, positive correlation is shown for one year. Of the remaining two years, one shows no correlation, the middle class falling below both extremes, while the other indicates positive correlation, the upper class exceeding the lower, but the middle class exceeding both. When averages for each of the original classes are noted, positive correlation is indicated. A gradual increase is shown through the first six classes compared. The last class falls considerably below the two preceding ones.

Another comparison is afforded in this study of the relation of total score to yield which was not possible in case of any of the separate characters. Since, according to the score card, the upper third class of ears represented in Table XX includes absolutely the best ears that could be found among those tested, the yield of this group should exceed that of any other "third" group represented in any of the preceding tables. Such a comparison must obviously be made between groups in which the same years are represented. By omitting the years 1906 and 1907 in data for Minnesota No. 13, all of them are comparable for the purpose mentioned. The averages thus obtained are represented in Table XXI.

Obviously the positive correlation indicated in Table XX becomes of doubtful significance in the light of this final comparison. In the first place, the upper third class for total score is now slightly exceeded by the middle third class. Further than this, it is exceeded by two of the other six groups, namely, "weight," and "variety character." It is equalled by three other groups, namely, "length," "tips," and "kernel uniformity." As a matter of fact, the differences among the seven groups amount to nothing.

TABLE XXI

COMPARISON OF UPPER THIRD CLASS FOR TOTAL SCORE WITH HIGHEST THIRD CLASS FOR EACH OF THE OTHER CHARACTERS

Character	Minn. No. 13	Minn. No. 161
	Bu.	Bu.
Total score (upper third class)	58.3	61.3
Total score (middle third class)	58.4	....
Length	58.3	61.7
Weight	58.4	61.2
Circumference	57.9	62.0
Shelling percentage	58.2	61.5
Butts	58.0	61.6
Kernel uniformity	58.3	61.5
Tips	58.3	61.9
Variety character	58.7	61.9

In the case of Minnesota No. 161, the highest scoring group suffers even more strikingly by this comparison, being in fact the lowest yielding of all the groups but one, namely, weight.

APPLICATION OF STATISTICAL METHOD TO DATA

Relation between any two characters or factors can be determined, when sufficient data are at hand, by assembling them into a so-called correlation table. This has been done in Table XXII with the data from University Farm for Minnesota No. 13. These alone were used because in the other cases there were too few to be treated by this method.

On the horizontal line at the top of the table appear the classes for total score. These classes have been arranged in the same manner as in other tables in Part I. On the vertical line appear the corresponding classes for yield.

These classes do not represent the actual total scores or the actual yields, as will at once be apparent. Instead of that, both yield and total score have first been reduced to terms of 100 by considering the average for each of the above two factors as 100, and referring the values for each ear to this. For instance, if the average yield of all ears in 1911 was 56 bushels, this was taken as 100. A yield of 54 bushels, then, was equivalent to 98.2; a yield of 60 bushels, 107, and so on.

The reason for expressing the values in this form is that it was necessary to include all years in one table in order to have sufficient data for this type of analysis and the different years were otherwise not comparable. It will readily be seen that a yield of 60 bushels per acre for one year may not indicate a higher yielding capacity on the part of the ear which it represents than a yield of 40 bushels for another year. Similarly an ear which scores 85 may not be inherently different from an ear grown during another year which scores only 75, environment having affected the degree of expression of its characters.

TABLE XXII

CORRELATION BETWEEN TOTAL SCORE AND YIELD, MINNESOTA NO. 13 CORN—UNIVERSITY FARM

Yield classes	Total score classes							Total
	78	85	92	99	106	113	120	
80		1	3	2				6
85		1	1	11	5	1		19
90		1	6	17	11	2	1	38
95	1	5	13	36	6	6	1	68
100		3	13	21	19	5		61
105		3	12	27	19	3		64
110			6	14	14	2	1	37
115			1	9	2	3		15
120			1	1	3			5
125				1				1
Total	1	14	56	139	79	22	3	314

$r = +0.119 \pm 0.038$

It will readily be understood that since the classes for each of the two factors whose relation is to be studied increase from the upper left-hand corner of the table on the horizontal and vertical lines, the figures in the table, which represent the number of individuals occurring in each of the classes, would be parallel to the diagonal extending from the upper left-hand corner in case a distinct positive relation existed, and would be parallel to the diagonal extending from the upper right-hand corner if a distinct negative correlation existed.

A definite mathematical expression for the degree of relationship has been worked out, however, for data tabulated in this way. This expression is known as the "correlation coefficient." As a basis for this coefficient, perfect correlation is designated as 1. Accordingly +1 indicates perfect direct or positive correlation, and —1 represents perfect inverse or negative correlation. Amount or degree of correlation, therefore, is expressed in fractions of 1.

The correlation coefficient for total score and yield appears immediately beneath the table. It is +0.119 (r is a symbol adopted by statisticians for correlation coefficient). Immediately following the value for correlation coefficient, another value, 0.038 with the sign ±

before it, appears. This value is "the probable error of the coefficient of correlation." It is designed to test the statistical significance of the correlation coefficient. By "statistical significance" is meant significance as affected by the number of individuals involved in the study. Obviously the larger the number of the data the more trustworthy are the indications which their analysis presents. That is to say, a correlation coefficient of 0.119 obtained for 100 individuals evidently will be very much less trustworthy than the same correlation coefficient obtained for 500. This is because certain values will be thrown in one direction or another by mere chance, and the larger the number of data, the greater the possibility that an equal number of these fluctuations will go in opposite directions, thus neutralizing each other. The calculated probable error increases in size, therefore, as the number of individuals decreases.

Concretely, the calculated probable error as applied to the correlation coefficient means that the chances are even that the true correlation coefficient falls within a range represented by the calculated correlation coefficient, plus and minus the calculated probable error. In other words, the chances are even that the true correlation coefficient in the present instance lies between 0.157 (0.119+0.038) and 0.081 (0.119 — 0.038).

It is evident from the above that the significance of any correlation coefficient depends upon how it compares in magnitude with its probable error. The following table illustrates this concretely:

Chances that the true correlation coefficient is within the limit established by

1 time the probable error=even
2 times the probable error= 4.5 to 1
3 times the probable error= 21 to 1
4 times the probable error=142 to 1

and so on until at nine times the probable error the chances are about one billion to one.

In Table XXIII are presented the correlation coefficients with their probable errors for each of the characters studied. The correlation tables are given in the appendix.

Out of the nine correlation coefficients appearing in the table, two (possibly three) are large enough to have possible significance. Chances are 21 to 1 that positive correlation exists in the case of total score. They are considerably greater than 21 to 1 that such correlation exists in the case of shelling percentage. This of itself is a contradiction, however, for as was noted in the discussion of the facts set forth in Table XXI, there is no group of ears so good from the score-card standpoint as the highest scoring ears, hence none should give so great a correlation with yield.

TABLE XXIII

CORRELATION COEFFICIENTS FOR THE VARIOUS CHARACTERS AND YIELD

Character or type	Cofficient of correlation (Tables XL to XLVIII)	
Length	+0.098	±0.040
Weight	+0.047	±0.044
Circumference	—0.052	±0.041
Shelling percentage	+0.157	±0.043
Butts	+0.006	±0.037
Tips	+0.030	±0.038
Kernel uniformity	+0.048	±0.037
Variety character	+0.033	±0.037
Total score	+0.119	±0.038

Chances are more than 4.5 to 1 that positive correlation exists in the case of length. In all of the other cases, chances are either only slightly greater, slightly less, or considerably less than 1 to 1 that correlation exists.

In conclusion it must be noted that those correlation coefficients which appear to be significant are significant from a statistcial standpoint only. They are certainly not significant from a practical standpoint. Many plant breeders consider that a correlation coefficient must be not less than 0.5 to be of significance from their standpoint. However, disregarding any arbitrary limit, it is perfectly obvious that none of the present coefficients indicate sufficient increases as a result of selection of better ears to make it worth while to expend time and labor on selection. Furthermore, it should be noted again that in view of the test applied to total score in Table XXI, even the higher correlation coefficients are of doubtful statistical significance.

The above conclusion applies with equal force to all of the results from all of the analyses of the ear-to-row data.

PART II. SELECTED EAR TYPES

The investigation of selected ear types was begun in 1914. From five to ten selections representing each of the following types were made from a crib of Minnesota No. 13 corn at University Farm: Show (these were the very best ears obtainable according to the score card standard), small, thick, elongated, poor tips, good tips, poor butts, good butts, and tapering. Each of these ears (except "good tips," which were omitted through an error) was planted in a separate row. A check row was planted between the groups of five rows. The seed planted in the check rows was a composite of all of the ears represented in the test.

Half of the seed from these ears was planted at Monticello, about forty miles north of University Farm, in exactly the same way.

In 1915 a somewhat different plan was followed. A much larger number of ears representing each character or type was selected, and all of the ears of one type were shelled together and planted in a plot instead of by the ear-to-row method. Each plot consisted of four rows, the object being to use the middle two rows for the yield test in order to overcome possible unequal competition with adjacent rows of another type. It was found, however, that there was no such unequal competition. That is to say, when the outer rows of the respective plots were compared, the rank of each plot as regards yields was substantially the same as when the middle rows were compared. For this reason the yield from the entire plot was used in all of the comparisons appearing in the tables which follow. The types of ears selected for this test were as follows: Show, elongated, short thick, tapering, cylindrical, small, smooth, rough, medium smooth, high in shelling percentage, low in shelling percentage, and medium in shelling percentage. These ears were selected at random from the crop of the previous year's experiment. That is to say, the long slender ears were not selected from the progeny of the corresponding parent ears of the previous year, the short thick ears from the progeny of short thick, and so on, but were selected from any and all progeny.

The season of 1915 was extremely unfavorable for corn in Minnesota, hence the crop was very immature. In fact, that on the test plots was not far past the roasting-ear stage when harvested. No distinct difference in the degree of maturity of the different plots was observable, however, so the results are probably not materially affected by this condition of the crop.

The experiment was repeated in 1916, on the same plan as was followed in 1915. It was necessary, however, to go outside of the Station to obtain seed. Seed of Minnesota No. 13 was obtained from E. G. Enestvedt, Sacred Heart. This is substantially the same latitude as University Farm. The corn, however, averages somewhat larger than that grown at University Farm and may be somewhat later maturing. The general character of the ears selected is shown in Figures 1 to 9. The ears shown are typical of the groups. The same general character was shown by the ears selected in 1915.

RESULTS

Detailed data from the 1914 experiment, University Farm, are presented in Table XXIV. The yield for each ear row is given as well as the average yield for each type of ear. At the foot of the table is given the rank of each type in yield and the average weight of the parent ears of each type in grams.

TABLE XXIV

YIELD PER ACRE OF INDIVIDUAL EARS OF VARIOUS TYPES, MINNESOTA NO. 13 CORN—UNIVERSITY FARM, 1914

	Character of ears								
	Show	Small	Thick	Elongated	Poor tips	Good butts	Poor butts	Tapering	Check
	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
	72.9	69.5	73.7	68.9	64.8	71.0	70.3	69.7	65.5
	64.0	65.8	73.5	68.7	62.5	61.2	58.1	59.6	64.4
	74.0	62.2	76.6	55.1	64.7	61.8	70.3	58.9	73.7
	72.5	....	62.6	64.8	52.2	70.0	65.8	73.7	67.6
	57.5	....	75.0	66.0	56.7	59.3	65.2	57.7	69.9
	70.6	....	65.0	....	61.2	....	74.3	63.3	64.1
	71.7	....	....	....	64.8	....	73.5	....	63.2
	70.4	....	....	....	58.6	....	56.7	....	58.2
	71.7	....	....	....	....	....	....	....	67.8
	63.2	....	....	....	....	....	....	....	69.3
	....	....	....	....	....	....	....	....	65.6
Average ..	68.8	66.7	71.1	64.7	60.7	64.7	66.8	63.5	66.3
Rank	2	4	1	5	7	5	3	6	....
Av. weight parent ears, grams....	9.25	6.75	10	8	8.75	8.75	9.25	8.25	....

It will be noted that some of the types are at a decided disadvantage owing to the small number of yield results obtained for them. This is notably true of the "small" type and to a lesser degree of "good butts" and "elongated."

TABLE XXV

RELATION OF WEIGHT OF EARS TO YIELD, MINNESOTA NO. 13 CORN—UNIVERSITY FARM, 1914

	Lower third	Middle third	Upper third
	Bu.	Bu.	Bu.
	62.2	64.0	72.9
	65.8	72.5	74.0
	55.1	57.5	70.6
	62.5	71.7	76.6
	66.0	71.7	62.6
	69.5	63.2	75.0
	70.4	73.5	73.7
	64.7	65.0	64.8
	52.2	68.9	64.8
	56.7	68.7	58.1
	71.0	64.8	70.3
	59.3	61.2	65.8
	59.6	61.8	74.3
	73.7	70.3	73.5
	63.3	65.2	69.7
	....	56.7	58.6
	....	....	70.0
Average	63.5	66.0	69.1

Superficially the most striking figures in the table are the high yields of "thick" and "show" ears and the low yield of "poor tips." Closer examination of the table seems to indicate that in the case of

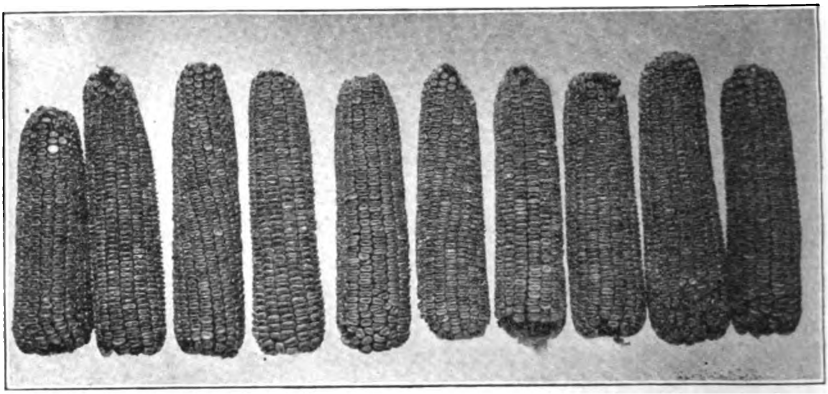

Fig. 1. Representative Rough Ears (1916 Test)

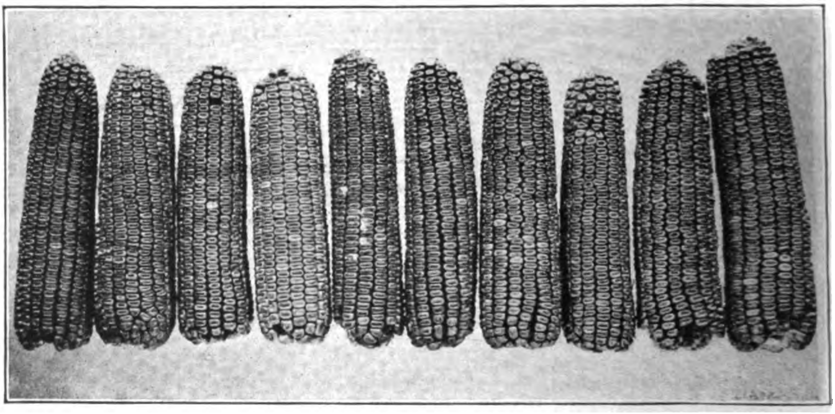

Fig. 2. Representative Medium Smooth Ears (1916 Test)

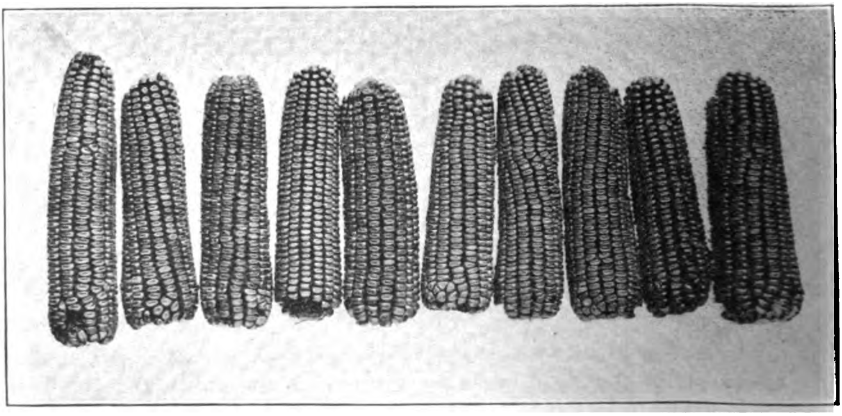

Fig. 3. Representative Smooth Ears (1916 Test)

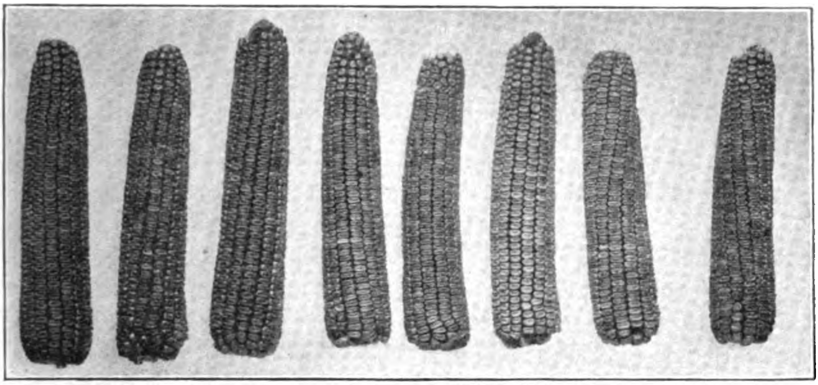

Fig. 4. Representative Long Slender Ears (1916 Test)

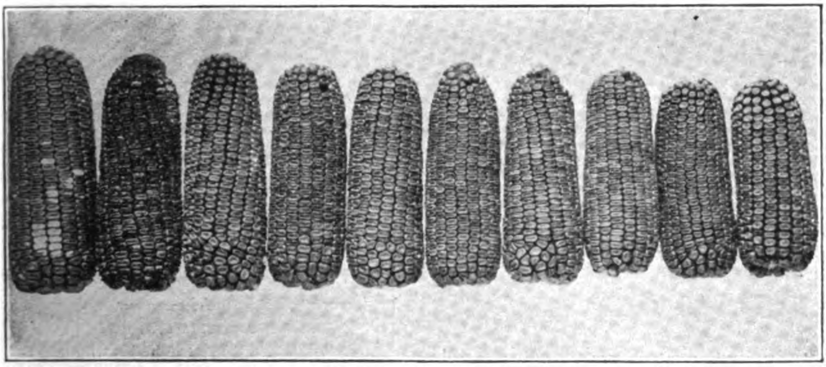

Fig. 5. Representative Thick Ears (1916 Test)

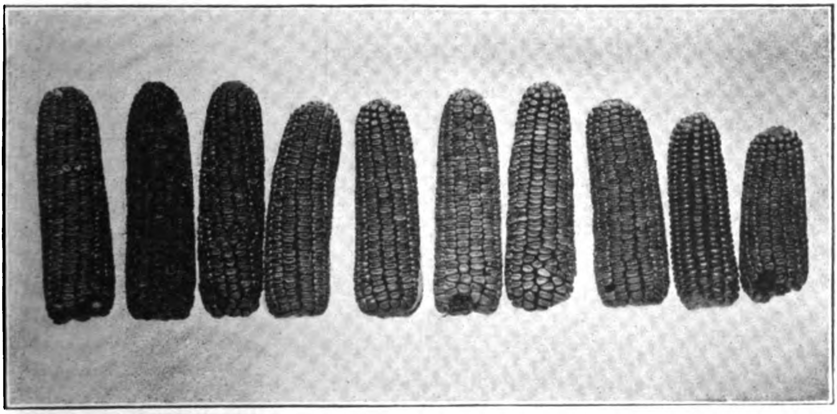

Fig. 6. Representative Small Ears (1916 Test)

the first two, these yields are associated with the weight of the ears. The relation of weight to yield is rather strikingly shown in Table XXV. The correlation coefficient for these data has been determined as 0.324 ± 0.063.

In Table XXVI are presented the corresponding data for Monticello. It must not be assumed that these figures constitute a definite check on the University Farm results. The seed used was not acclimated, a fact which might be expected to materially affect the relation of size of ear and yield, in particular. As a matter of fact, the data indicate that the relation found at University Farm was reversed at Monticello. This is most clearly shown in Table XXVII, which corresponds exactly to Table XXIV. The correlation coefficient in this case is -0.291 ± 0.066, somewhat less than that for University Farm data, but significant nevertheless.

TABLE XXVI

YIELD OF INDIVIDUAL EARS OF VARIOUS TYPES, MINNESOTA NO. 13 CORN—MONTICELLO, 1914

	Character of ears								
	Show	Small	Thick	Elongated	Poor tips	Good butts	Poor butts	Tapering	Check
	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
	26.5	36.7	29.5	31.3	33.1	36.1	25.0	30.8	32.5
	28.7	35.4	31.6	32.5	30.1	24.2	18.1	33.5	36.0
	27.3	32.3	29.8	31.0	29.0	28.7	33.4	23.2	30.2
	29.2	30.2	28.8	26.1	26.4	27.7	24.0	35.0	30.3
	31.2	....	30.1	26.5	38.2	22.5	29.9	43.4	26.6
	27.6	....	....	24.4	28.7	....	32.7	28.1	27.0
	36.1	....	....	....	31.3	....	21.6	....	27.6
	27.6	....	....	....	24.3	....	30.5	....	30.1
	30.8	....	....	....	....	....	....	....	34.3
	28.7	....	....	....	....	....	....	....	35.7
Average ..	29.4	33.8	29.9	28.6	30.1	27.8	26.9	32.3	31.0
Rank	5	1	4	6	3	7	8	2	....
Av. weight parent ears, grams....	9.25	6.75	10	8	8.75	8.75	9.25	8.25	....

The above does not explain all the disagreements between University Farm and Monticello data, however. Thus "poor tips," which showed such a strikingly low yield at University Farm, yielding 4 bushels less than "good butts" which is equal to it in ear weight, exceeds the latter at Monticello. This low yield, therefore, probably has nothing to do with the character of the ears, but is purely accidental.

Since each of the ears used in this experiment was measured, it is possible to group the entire lot for a study of relation of length to yield. The result is shown in Table XXVIII. Obviously, there is no relation.

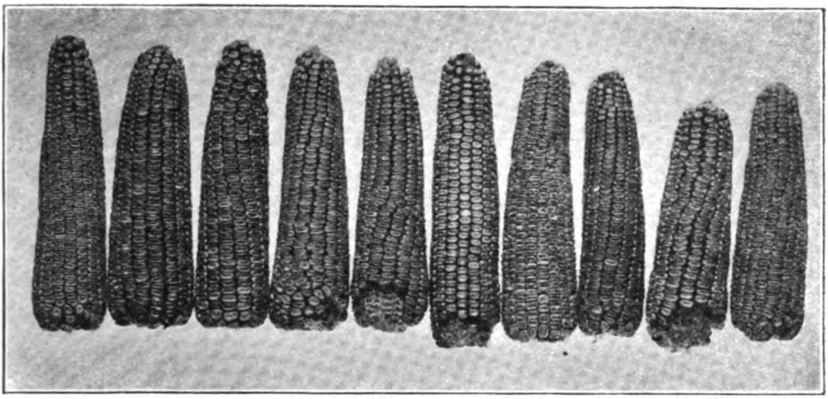

Fig. 7. Representative Tapering Ears (1916 Test)

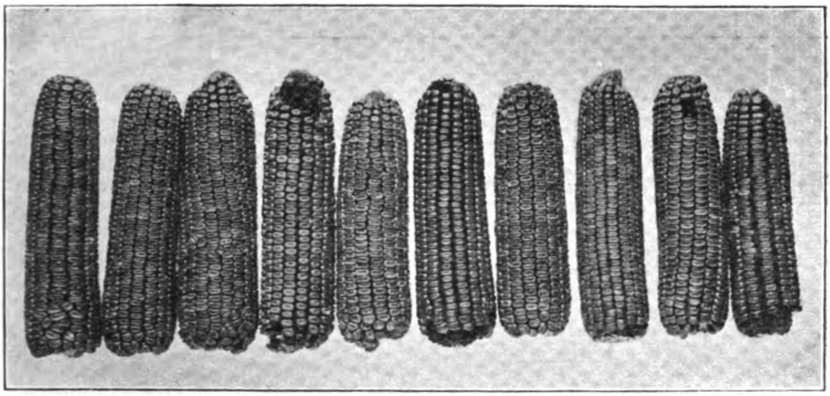

Fig. 8. Representative Cylindrical Ears (1916 Test)

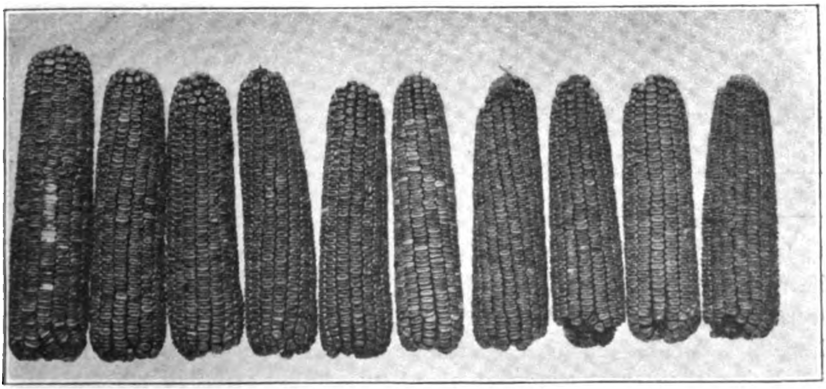

Fig. 9. Representative Show Ears (1916 Test)

TABLE XXVII

Relation of Weight of Ear to Yield, Minnesota No. 13 Corn—Monticello, 1914

	Lower third	Middle third	Upper third
	Bu.	Bu.	Bu.
	20.3	28.7	26.5
	35.4	29.2	27.3
	21.1	31.2	27.6
	30.1	36.1	29.8
	24.4	30.8	28.8
	32.3	28.7	30.1
	36.7	31.6	29.5
	27.6	31.3	26.5
	29.0	32.5	31.3
	26.4	31.0	18.1
	38.2	33.1	33.4
	36.1	28.7	24.0
	22.5	28.7	32.7
	43.4	25.0	21.6
	33.5	29.9	30.8
	35.0	30.5	24.3
	28.1	....	27.7
Average	31.5	30.4	27.6

TABLE XXVIII

Relation of Length of Ear to Yield, Minnesota No. 13 Corn—University Farm, 1914

	Lower third	Middle third	Upper third
	Bu.	Bu.	Bu.
	63.2	64.0	74.0
	71.7	70.6	72.5
	69.5	71.7	68.9
	65.8	70.4	68.7
	62.2	64.8	55.1
	76.6	71.0	64.8
	62.6	65.2	66.0
	75.0	70.3	61.2
	65.0	61.2	58.6
	62.5	72.9	58.1
	64.7	64.8	65.8
	61.8	52.2	74.3
	70.0	69.7	73.5
	59.3	56.7	64.1
	58.9	56.7	57.5
	57.7	73.5	66.0
	73.7	....	70.3
	....	....	59.6
Average	65.9	65.9	65.5

In Table XXIX the data are similarly arranged for the study of the relation of number of rows per ear to yield. It is apparent, when averages for upper, lower, and middle third classes are compared, that there is a decided positive relation. Roughly, the number of rows is simply another measure of the weight of the ears, as reference to Table XXX will show.

TABLE XXIX

RELATION OF NUMBER OF ROWS TO YIELD, MINNESOTA NO. 13 CORN—UNIVERSITY FARM, 1914

	Number of rows					Lower third	Middle third	Upper third
	12	14	16	18	20			
	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
	55.1	64.8	73.7	73.7	76.6	....	....	....
	....	66.0	69.7	73.5	75.0	....	....	....
	....	61.2	56.7	62.6	61.2	....	....	....
	....	70.3	72.9	65.0	....	....	....	....
	....	58.1	64.0	64.8	....	....	....	....
	....	65.2	74.0	74.3	....	....	....	....
	....	59.6	72.5	73.5	....	....	....	....
	....	57.7	57.5	58.9	....	....	....	....
	....	63.3	70.6	....	....	....	....	....
	....	....	71.7	....	....	....	....	....
	....	....	70.4	....	....	....	....	....
	....	....	71.7	....	....	....	....	....
	....	....	63.2	....	....	....	....	....
	....	....	68.9	....	....	....	....	....
	....	....	68.7	....	....	....	....	....
	....	....	64.8	....	....	....	....	....
	....	....	62.5	....	....	....	....	....
	....	....	64.7	....	....	....	....	....
	....	....	52.2	....	....	....	....	....
	....	....	56.7	....	....	....	....	....
	....	....	58.6	....	....	....	....	....
	....	....	71.0	....	....	....	....	....
	....	....	61.8	....	....	....	....	....
	....	....	70.0	....	....	....	....	....
	....	....	59.3	....	....	....	....	....
	....	....	70.3	....	....	....	....	....
	....	....	65.8	....	....	....	....	....
Average	55.1	62.9	66.1	68.3	67.6	63.8	66.1	67.4

TABLE XXX

RELATION OF WEIGHT OF EARS TO YIELD AND TO NUMBER OF ROWS PER EAR—UNIVERSITY FARM, 1914

Type	Average yield per acre	Average weight parent ears	Average number of rows
	Bu.	Oz.	
Good	68.8	9.25	16.0
Small	66.7	6.75	15.6
Short thick.......................	72.3	10.0	18.7
Elongated slender................	64.7	8.0	14.8
Poor tips........................	60.7	8.75	16.0
Good butts.......................	64.7	8.75	16.8
Poor butts.......................	66.8	9.50	15.8
Tapering	63.5	8.25	15.4

In Table XXXI is given the summary for 1915. In the left-hand columns are given the yields for each of the duplicate plots, and in the right-hand columns the rank in yield of each type. The only types for which there is any indication of relation to yield are "show" and "small," both of which appear to be low yielders. Evidently it made no difference in this test whether ears had a high or low shelling percentage. Both of these types are high yielders, according to these data. The shelling percentages were respectively, 87.5 and 79.5.

TABLE XXXI

Relation of Ear Types to Yield, Minnesota No. 13 Corn—University Farm, 1915

Character of ears	Yield per acre		Rank as regards yield		
	Plots Series I	Plots Series II	Plots Series I	Plots Series II	No. of ears in test
	Bu.	Bu.			
Show	20.4	17.7	10	10	30
Elongated	23.2	22.2	7	4	44
Short thick	23.9	20.1	5	7	50
Tapering	24.2	19.8	4	9	35
Cylindrical	23.4	16.2	6	11	29
Small	20.6	15.7	9	12	40
Smooth	22.3	20.4	8	6	60
Rough	19.9	21.2	11	5	50
Medium smooth	19.8	23.0	12	3	48
High shelling percentage	24.4	24.4	3	1	17
Low shelling percentage	24.9	24.1	1	2	17
Medium shelling percentage	24.6	19.4	2	8	17

TABLE XXXII

Relation of Ear Types to Yield, Minnesota No. 13 Corn—University Farm, 1916

Character of ears	Yield per acre		Rank as regards yield		
	Plots Series I	Plots Series II	Plots Series I	Plots Series II	No. of ears in test
	Bu.	Bu.			
Show	42.7	49.5	8	3	29
Elongated	41.8	39.9	9	8	27
Short thick	44.0	39.5	5	9	42
Tapering	44.7	49.9	4	2	37
Cylindrical	46.9	34.2	3	12	10
Small	50.5	45.6	1	4	40
Rough	41.6	41.4	10	7	29
Medium smooth	50.0	38.4	2	10	25
Crooked rows	43.4	42.1	6	5	11
High shelling percentage	38.1	41.6	12	6	17
Low shelling percentage	40.8	50.0	11	1	17
Medium shelling percentage	43.2	37.4	7	11	18

Table XXXII presents corresponding data for 1916. Elongated and rough ears appear to be rather low yielders, while tapering and small ears appear to be high yielders.

The data analyzed for relation of weight to yield are presented in Tables XXXIII and XXXIV, for 1915, and Table XXXV, for 1916. Table XXXIV indicates a slight relation; so slight, however, as to be practically insignificant. Table XXXV, for 1916, indicates a negative relation altho the yield of ears of average size is practically equal to that of ears of largest size.

TABLE XXXIII

Relation of Weight of Ears to Yield—University Farm, 1915

Type of ears	Average weight parent ears	Rank as regards yield
	Grams	
Show	199	8
Elongated slender	193	1
Short thick	175	2 and 3
Tapering	188	2 and 3
Cylindrical	180	7
Small	108	9
Smooth	155	5
Rough	175	6
Medium smooth	177	4

TABLE XXXIV

Relation of Weight of Ears to Yield—University Farm, 1915

	Lower third	Middle third	Upper third
	Bu.	Bu.	Bu.
	22.0	22.0	19.1
	18.2	19.8	22.7
	21.4	21.4	22.0
	20.6	20.6	....
Average	20.5	20.9	21.3

TABLE XXXV

Relation of Weight of Ears to Yield, Minnesota No. 13 Corn—University Farm, 1916

	Lower third	Middle third	Upper third
	Bu.	Bu.	Bu.
	50.5	44.0	41.8
	45.6	39.5	39.9
	46.9	38.1	43.4
	34.2	41.6	42.1
	41.6	40.8	43.2
	41.4	50.0	37.4
	44.7	50.0	42.7
	49.9	38.4	49.5
Average	44.5	44.1	42.5

MAINE DATA ON RELATION OF WEIGHT OF EARS TO YIELD

Reference has been made to certain data gathered by Pearl and Surface, of the Maine Agricultural Experiment Station, in their experiments in breeding sweet corn. The writers have compiled such of these data as bear upon the relation of weight of ears to yield and the results are presented in summarized form in Table XXXVI.

TABLE XXXVI

RELATION OF WEIGHT OF EAR TO YIELD*
"Type" Corn

	Yield	Average weight of parent ears	Weight of lightest parent ear in class	Weight of heaviest parent ear in class	Number of ears in class
	Bu.	Grams	Grams	Grams	
1908					
Total weight per ear					
Lower third	18.4	81.3	71.5	88.0	33
Middle third	16.9	94.5	88.4	99.5	34
Upper third	17.4	111.0	100.0	125.0	33
Weight per ear of shelled corn					
Lower third	18.1	63.4	56.7	68.0	33
Middle third	17.4	74.9	68.6	79.9	34
Upper third	17.4	87.4	80.0	112.3	33
1909					
Total weight per ear					
Lower third	10.3	77.0	62.0	96.5	15
Middle third	9.5	118.0	98.0	131.5	16
Upper third	10.0	141.5	132.0	157.0	16
Weight per ear of shelled corn					
Upper third	10.2	65.2	49.5	77.5	15
Lower third	9.6	94.9	78.0	107.0	16
Middle third	9.8	114.6	108.5	126.5	16

* Data by Pearl and Surface, Maine Agr. Exp. Sta.

Data from a two years' investigation are included in the table. The study has been made on the basis of both total weight of ear and weight of shelled corn per ear. In the second, third, and fourth columns are given, respectively, the average weight of ears in each of the three classes and the weight of the lightest and heaviest ears in each class. A slight negative correlation is indicated. When analyzed by the statistical method for the determination of correlation coefficient this is found to be —0.033 ± 0.067 and —0.023 ± 0.067 for total weight of parent ear with subsequent yield and shelled corn weight per parent ear and subsequent yield, respectively, in 1908. Obviously these coefficients indicate no correlation, since in both cases the probable error exceeds the coefficient. Because of the smaller number of ears used, this latter analysis was not made for the 1909 data. By comparison it is readily seen, however, that the relation amounts to nothing.

PART III. SELECTION FOR YIELD AND EAR TYPE VS. SELECTION FOR EAR TYPE ALONE

Simultaneously with the ear-to-row work which has already been discussed, a plot was maintained in which ears were selected annually on the basis of the character of the ear only. While this selection was not based on the detailed scoring which formed a part of the ear-to-row work, a conscious effort was made each year to adhere to a standard type of ear. Minnesota No. 161 was the variety used. A comparison with the ear-to-row results for this variety is shown in Table XXXVII.

TABLE XXXVII

SELECTION FOR YIELD AND TYPE VS. SELECTION FOR TYPE ALONE

Year	Selection	Field cured weight	Difference
		Bu.	Bu.
1904	Yield and ear type	51.4	+1.3
	Ear type	50.1	
1905	Yield and ear type	75.8	+21.1
	Ear type	54.7	
1906	Yield and ear type	57.3	
	Ear type	57.6	—0.3
1907	Yield and ear type	64.1	+7.8
	Ear type	56.3	
1908	Yield and ear type	56.3	
	Ear type	56.5	—0.2
1909	Yield and ear type	62.5	
	Ear type	62.6	—0.1
1910	Yield and ear type	44.6	+11.3
	Ear type	33.3	
1911	Yield and ear type	62.5	+4.1
	Ear type	58.4	
	Average of yield and ear type	59.3	+5.6
	Average of ear type	53.7	

As an average of the eight years in the test there is a difference of 5.6 bushels in favor of the ear-to-row selection. The latter, moreover, had the advantage in five of the eight years. During the other three there was an insignificant difference in favor of the ear type alone.

The investigation does not afford any direct evidence on the question of the comparative effect of selection for yield alone with selection for yield and type. Since type of ear does not, according to the preceding data, bear any important relation to yield, it is fair to assume that the entire difference of 5.6 bushels may be credited to yield selection.

SUMMARY OF EXPERIMENTAL RESULTS

I. EAR-TO-ROW TESTS

In the ear-to-row tests carried on at University Farm and at three outlying stations, West Concord, Willmar, and Cokato, a large number of ears selected each year from the highest yielding rows were carefully scored in the laboratory on the basis of the customary corn score card. Several of the highest scoring ears (thirty-six or more in most cases) were used for each succeeding year's ear-to-row planting. The value of this intensive selection was studied by grouping the ears in classes according to the size of their score for each of various characters and noting the comparative average yields of these groups. A summary of the results according to the final groupings is given in Table XXXVIII. The figures for University Farm represent a much larger volume of data than those for the outlying stations and are regarded as more trustworthy.

TABLE XXXVIII

SUMMARY OF YIELDS FOR LOWER, MIDDLE, AND UPPER THIRD CLASSES

Ear character	University Farm					
	Minnesota No. 13			Minnesota No. 161		
	Lower	Middle	Upper	Lower	Middle	Upper
	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
Length	57.5	58.0	58.3	62.1	62.0	63.3
Weight	57.0	58.4	57.9	62.3	62.1	62.6
Shelling percentage	57.3	58.1	58.2	63.1	62.4	62.3
Circumference	57.9	57.7	57.5	62.9	61.6	62.7
Butts	57.5	57.6	57.4	62.6	62.9	62.0
Tips	57.2	57.7	57.5	62.3	62.3	62.9
Kernel uniformity	57.2	57.1	57.7	62.6	62.7	62.0
Variety character	57.1	57.4	57.9	60.6	61.9	61.3
Total score	56.9	57.7	57.9	59.9	60.7	61.3
	Outlying Stations					
	West Concord			Willmar		
	Minnesota No. 13			Minnesota No. 161		
	Lower	Middle	Upper	Lower	Middle	Upper
	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
Length	33.8	36.9	35.3	47.1	47.5	47.5
Weight	35.5	37.5	37.0	52.0	51.4	52.0
Shelling percentage	37.7	37.1	36.9	46.7	46.9	45.8
Circumference	36.5	35.2	37.2	48.1	47.2	47.5
Butts	37.4	36.0	36.2	49.2	48.8	48.4
Tips	36.7	38.3	37.6	45.4	48.5	48.8
Kernel uniformity	38.5	38.4	37.1	49.0	48.6	47.7
	Cokato			Cokato		
	Minnesota No. 332			Minnesota No. 13		
	Lower	Middle	Upper	Lower	Middle	Upper
	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
Length	50.7	51.8	48.6	49.5	50.5	47.1
Weight	49.9	51.5	49.9	47.5	50.6	49.8
Shelling percentage	52.3	51.5	48.8	49.2	48.9	49.4
Circumference	48.1	49.9	52.9	48.1	50.8	50.6
Butts	51.0	50.2	49.9	50.3	48.6	48.9
Tips	51.1	52.0	51.9	49.2	49.3	49.1
Kernel uniformity	51.0	50.4	49.9	49.7	48.3	49.5

An additional test of correlation has been made with Minnesota No. 13, University Farm, the correlation coefficient having been worked out for each of the characters. By this test even statistical significance can be attached to indication of correlation in only two or possibly three cases. The correlation coefficients for total score, shelling percentage, and length are respectively three, three and a half, and two and a half times their probable errors. (See Table XXIII.)

The validity of total score as an index to yield has been further tested by comparing the yield of the "upper third" group of total score ears with the highest yielding third group for each of the other characters. By this comparison the highest scoring ears become only average. In the case of Minnesota No. 13 they exceed three groups, are surpassed by two, and are equalled by three. In the case of Minnesota No. 161 they are surpassed by all but one group. As a matter of fact the yields are very close in both cases. (See Table XXI.)

In view of this final analysis it is very doubtful if any of the indications of correlation found in any of the analyses of all the data are even of statistical significance. It is, of course, clear that they are not of practical significance as the differences in any case are very small.

2. SELECTED EAR TYPES

Definite types of ears, as show ears, elongated ears, short thick ears, tapering ears, etc., were selected from a lot of corn, and each type planted in a separate plot. This method was continued three years. The selection was not continuous. The various types were not selected respectively from the crop produced the preceeding year from a corresponding type. The results in brief are as follows:

1914. Show ears and thick ears were outstanding in yield. A significant relation existed between weight and yield (Table XXV). The correlation coefficient for weight and yield was $+0.324 \pm 0.063$. No relation between length and yield was shown.

1915. Show ears and small ears appeared to be low yielders. No relation to yield was indicated in case of any of the other types. A very slight indication of relation between weight and yield was shown. (Tables XXXI, XXXIII, and XXXIV.)

1916. Some positive relation was indicated in the case of tapering and small ears and some negative relation appeared to exist in the case of long slender and rough ears. (Table XXXII.) Thus no consistent relation is shown when results for different years are compared.

3. SELECTION FOR YIELD AND EAR TYPE VERSUS SELECTION FOR EAR TYPE ALONE

Simultaneously with the carrying on of the ear-to-row work described under I, a plot of Minnesota No. 161 was maintained in which ears were selected continuously on the basis of the character of the ear only. As an average of eight years, the ear-to-row method outyielded the exclusive ear selection method by 5.6 bushels.

GENERAL DISCUSSION OF RESULTS

With reference to their method of fertilization, field crops are of two kinds, namely, those which are generally self-fertilized, and those which are often cross-fertilized. Familiar examples of the former are wheat, oats, and barley; of the latter, corn and rye.

If all the kernels produced by a single wheat plant were planted, a very high degree of similarity among all of the resulting plants would be seen. In fact, the only differences would be fluctuations in size due to inequalities of soil or other environmental conditions. If, on the other hand, all of the kernels from an ear of average corn were planted, considerable differences among the resulting plants would be seen, differences in shape of kernels, shape of ears, number of rows per ear, in many cases in color of kernels, and many others which could not be ascribed to differences in environmental conditions. The wheat plant is pure for all of its transmissible or heritable characters. This obviously must, under normal conditions, always be true of the wheat plant, for the pollen, containing the male reproductive elements, and the egg cell, or female reproductive cell, which unite to form the new individual are produced from generation to generation by the same plant. The male and female cells are identical with reference to the qualities or potential characters which they contribute to the new individual. In the case of corn, however, the situation is quite different. The potential characters possessed by any ear have been contributed by a large number of plants. Male and female reproductive elements are quite unlike in the majority of cases. Necessarily unlike progeny must be the result.

But the degree of variability in corn may be reduced by artificial means. By close and long-continued selection a similarity of type may be obtained. Such similarity is due to the fact that the selection tends toward the production of a variety in which the inheritance for the selected characters approaches the condition in self-fertilized plants. That is to say, for these characters the male and female reproductive cells tend to become of like nature.

It is now generally recognized that inbreeding in cross-fertilized plants tends to reduce vigor. Self-fertilization in corn, for example, causes an immediate reduction in yield. After continuous self-fertilization a state is reached in which a purity of type is obtained. Such self-fertilized strains are very inferior from the standpoint of yield. After this purity of type is reached, however, continued self-fertilization does not further decrease yield. (Shull 1910.) (East and Hayes 1912.)

Reduced yields accompanying inbreeding are, according to the best genetic evidence, a direct result of increased gametic purity. That is, as the gametes or reproductive bodies which meet to form the new individual become more and more alike, the stimulus to growth resulting from the union decreases. Continued selection to a type, therefore, may be expected to tend toward the same reduction in yield. The reduction will take place much less rapidly than under artificial self-fertilization, because the approach to purity will be much less rapid.

A rather attractive interpretation of this well-known stimulus which very frequently accompanies heterozygosis, has recently been offered by Jones (1917). His hypothesis attributes this stimulus to an increased number of growth factors entering into the heterozygous individual as compared with the number contained in either of the parents. As factors are frequently linked in inheritance, it is considered impossible for a homozygous individual to contain as many growth factors as can be obtained in a heterozygous form.

The results presented in this paper show conclusively that close selection for high-scoring ears is of no practical value in increasing yield. The selection of high-yielding ears as determined by the ear-to-row method proved to be of considerable value as a means of increasing yield. Whether selection for yield plus selection for type will give as high a yield as selection for yield alone is not known. Close selection for any particular set of characters, we believe, tends to reduce yield if such selection succeeds in producing a uniform type. As evidence of results having been obtained, the Illinois selection for high and low protein and high and low oil may be given (Smith 1908). The figures in Table XXXIX are taken from Illinois Bulletin 128.

These results show that the standard variety gave an average yield for the four-year period of 4.4 bushels per acre more than the close-selected strain of low protein, and 15.9 bushels more than the average obtained for the high protein selection.

Similar results were obtained for high and low oil selections as compared with the standard. In selecting for a valuable character, as high protein, some sacrifice of yield may be worth while. This is clearly pointed out by Smith (1908). From the standpoint of a close approach to a score card type the breeder must determine the particular value of such approach for himself. The results of all experiments would surely tend to show that such score card selection might tend to a reduction in yield if long continued and if no new blood were introduced.

TABLE XXXIX

YIELDS OBTAINED IN VARIETAL TEST PLOTS

Year	High protein	Low protein	High oil	Low oil	Standard variety
1903	27.3	37.7	32.7	41.3	40.9 (Boone Co. White)
1904	32.1	55.5	41.9	40.5	53.7 (Boone Co. White)
1905	56.6	60.7	58.4	58.1	68.4 (Silver Mine)
1906	65.1	73.2	66.3	83.2	75.7 (Silver Mine) 87.9 (Leaming)
Average	45.3	56.8	49.8	55.8	61.2

A broad system of breeding for corn would seem, therefore, to be the correct procedure. Such a method is here given.

RECOMMENDED METHOD OF BREEDING

If the breeder is willing to use the ear-to-row method, the following plan is recommended. It is taken from the work of Montgomery (1909).

1. Select from 100 to 200 ears of the variety to be grown. If possible, select these ears in the field from those stalks which under competition give a good yield.

2. Make an ear-to-row test of these selected ears, saving half of the seed from each ear planted. From this ear-to-row test the 3 to 5 high-yielding ears may be determined.

3. Mix the remnants of the 3 to 5 high-yielding ears and plant the following year in a seed plot. Select all ears obtained which are fairly desirable, eliminating the very undesirable types.

4. Use the selected seed for field planting.

5. Give special attention to a part of the field so that a uniform stand may be obtained. Select enough seed from this part of the field for the entire acreage. Select seed in the fall from those stalks which under competition show ability to produce one or more good ears. Eliminate only the very undesirable types.

6. Continue the method outlined under 5 for a period of four or five years and then use the ear-to-row method as outlined under paragraphs 1 and 2.

For the grower who does not have time for accurate ear-to-row breeding the following plan is suggested:

1. Give special attention to a part of the field with regard to planting and cultivation. Select each fall before frost from those stalks which under competition show yielding ability. Do not select from stalks which clearly have unusual environmental advantages, such as more room for development, as these environmental variations are not inherited. Discard the very undesirable types but do not practice a close laboratory selection to type.
2. Continue the above plan each crop season.

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APPENDIX

TABLE XL

CORRELATION BETWEEN TOTAL SCORE AND YIELD

Yield classes	Total score classes							Total
	78	85	92	99	106	113	120	
80	..	1	3	2	..	..	..	6
85	..	1	1	11	5	1	..	19
90	..	1	6	17	11	2	1	38
95	1	5	13	36	16	6	1	68
100	..	3	13	21	19	5	..	61
105	..	3	12	27	19	3	..	64
110	..	..	6	14	14	2	1	37
115	..	..	1	9	2	3	..	15
120	..	..	1	1	3	..	..	5
125	..	..	..	1	..	..	..	1
Total	1	14	56	139	79	22	3	314

$r = +0.119 \pm 0.038$

TABLE XLI

CORRELATION BETWEEN SCORE FOR TIPS AND YIELD

Yield classes	Tip score classes										Total
	17	52	87	122	157	192	227	262	297	332	
80	2	..	2	..	1	1	..	..	..	..	6
85	5	2	1	5	4	1	1	..	..	..	19
90	7	2	9	5	4	3	4	..	..	4	38
95	16	4	19	13	10	5	..	1	..	..	68
100	13	4	16	14	5	6	3	..	..	..	61
105	7	5	15	17	7	6	5	2	..	..	64
110	5	2	9	10	6	3	..	..	2	..	37
115	6	..	3	1	3	..	1	..	1	..	15
120	..	..	1	1	..	2	1	..	..	..	5
125	1	..	..	..	..	..	..	..	..	..	1
Total	62	19	75	66	40	27	15	3	3	4	314

$r = +0.030 \pm 0.038$

TABLE XLII

CORRELATION BETWEEN SCORE FOR BUTTS AND YIELD

Yield classes	Butt score classes									Total
	30	45	60	75	90	105	120	135	150	
80	..	..	..	3	1	1	1	..	..	6
85	1	..	1	4	3	4	4	1	1	19
90	..	..	1	4	8	13	7	2	3	38
95	2	..	4	8	16	26	7	5	..	68
100	2	..	..	12	12	17	8	3	7	61
105	..	..	2	10	17	24	7	2	2	64
110	..	..	1	6	7	14	7	1	1	37
115	..	..	..	3	3	5	3	..	1	15
120	..	..	1	2	1	..	..	1	..	5
125	..	..	..	..	..	1	..	..	..	1
Total	5	..	10	52	68	105	44	15	15	314

$r = +0.006 \pm 0.037$

TABLE XLIII

Correlation Between Score for Kernel Uniformity and Yield

Yield classes	Kernel uniformity classes										Total
	56	65	74	83	92	101	110	119	128	137	
80	..	..	..	..	4	..	2	..	..	..	6
85	..	..	..	2	5	3	8	1	..	..	19
90	..	..	..	4	15	4	13	1	..	1	38
95	..	3	3	11	18	13	12	5	2	1	68
100	..	2	1	10	16	3	20	4	4	1	61
105	1	1	1	9	17	12	19	2	2	..	64
110	..	..	2	2	9	6	14	3	1	..	37
115	..	1	..	..	6	3	3	1	..	1	15
120	..	..	..	1	..	1	2	1	..	..	5
125	..	..	..	..	..	..	1	..	..	..	1
Total	1	7	7	39	90	45	94	18	9	4	314

r = + 0.048 ± 0.037

TABLE XLIV

Correlation Between Variety Character and Yield

Yield classes	Variety character classes									Total
	71	78	85	92	99	106	113	120	127	
80	..	1	..	4	..	1	..	..	..	6
85	..	1	1	2	7	6	2	..	..	19
90	..	1	2	3	13	16	3	..	..	38
95	1	2	9	13	16	12	5	10	..	68
100	2	3	6	7	14	14	11	4	..	61
105	..	3	6	14	16	18	6	..	1	64
110	2	1	1	5	8	10	6	4	..	37
115	..	..	1	1	5	6	1	1	..	15
120	..	..	..	1	..	3	1	..	..	5
125	..	..	..	..	..	1	..	..	..	1
Total	5	12	26	50	79	87	35	19	1	314

r = + 0.033 ± 0.037

TABLE XLV

Correlation Between Length of Ear and Yield

Yield classes	Length of ear classes							Total
	85	90	95	100	105	110	115	
80	1	1	..	1	1	..	..	4
85	..	2	6	4	5	1	..	18
90	1	2	9	7	7	2	1	29
95	2	2	20	18	18	3	..	63
100	1	2	19	6	24	3	..	55
105	1	3	18	16	15	2	..	55
110	..	1	5	9	16	..	2	33
115	..	..	6	3	3	1	..	13
120	1	..	1	..	1	..	..	3
125	..	..	..	..	1	..	..	1
Total	7	13	84	64	91	12	3	274

r = + 0.098 ± 0.040

TABLE XLVI

Correlation Between Circumference of Ear and Yield

Yield classes	Circumference of ear classes									Total
	60	90	93	96	99	102	105	108	111	
80	..	..	1	..	..	3	..	..	..	4
85	..	1	1	3	3	6	3	..	1	18
90	..	1	1	4	10	5	8	..	..	29
95	..	..	4	6	17	19	14	3	..	63
100	..	1	..	13	14	18	5	4	..	55
105	1	2	3	9	15	16	7	2	..	55
110	..	..	..	4	13	12	4	..	..	33
115	..	..	..	2	6	5	..	..	..	13
120	..	..	..	1	..	..	2	..	..	3
125	..	..	..	..	1	..	..	..	..	1
Total	1	5	10	42	79	84	43	9	1	274

r = − 0.052 ± 0.041

TABLE XLVII

Correlation Between Weight of Ear and Yield

Yield classes	Weight of ear classes												Total
	84	87	90	93	96	99	102	105	108	111	114	120	
80	1	..	..	1	1	..	..	..	..	..	..	..	3
85	..	..	2	3	1	4	..	3	3	..	..	..	16
90	..	..	1	4	6	5	4	..	6	..	1	..	27
95	2	..	4	5	8	9	5	8	1	7	4	..	53
100	1	1	5	5	8	6	10	5	3	1	..	..	45
105	2	..	1	3	12	10	6	5	3	2	..	1	45
110	..	..	..	2	9	3	5	5	3	..	..	..	27
115	..	..	..	3	2	2	1	2	..	..	2	..	12
120	..	..	..	1	..	..	..	1	1	..	..	..	3
125	..	..	..	..	..	1	..	..	..	..	..	..	1
Total	6	1	13	27	47	40	31	29	20	10	7	1	232

r = + 0.047 ± 0.044

TABLE XLVIII

Correlation Between Shelling Percentage and Yield

Yield classes	Shelling percentage classes							Total
	93.5	95.5	97.5	99.5	101.5	103.5	105.5	
80	1	..	1	..	..	1	..	3
85	..	1	6	2	2	5	..	16
90	1	5	5	4	5	5	2	27
95	1	10	11	14	12	4	1	53
100	..	3	11	11	10	9	1	45
105	1	1	8	13	12	8	2	45
110	..	2	2	12	7	2	..	27
115	..	..	..	5	4	2	1	12
120	..	..	..	..	2	1	..	3
125	..	..	..	..	1	..	..	1
Total	4	22	46	61	55	37	7	232

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BULLETIN 175 JULY 1918

The University of Minnesota

AGRICULTURAL EXPERIMENT STATION

FOURTH ANNUAL SEED LABORATORY REPORT

1916-1917

BY

R. C. DAHLBERG AND W. L. OSWALD

DIVISION OF PLANT PATHOLOGY AND BOTANY

UNIVERSITY FARM, ST. PAUL

HARVARD COLLEGE
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LETTER OF TRANSMITTAL

Minneapolis, Minn., March 30, 1918

To His Excellency, J. A. A. Burnquist,
Governor of Minnesota.

Sir:

I have the honor to transmit to you herewith the third annual report of the Seed Laboratory of the Minnesota Agricultural Experiment Station, for the year ending July 31, 1917. The report is prepared in accordance with the requirements of Chapter 141, H. F. 95, General Laws of Minnesota for 1913, entitled, "An Act to Regulate the Selling, Offering or Exposing for Sale, of Agricultural Seeds in this State and Providing Penalties for Violating the Same." The report will be published as a bulletin of the Agricultural Experiment Station.

Respectfully,
Marion LeRoy Burton,
President of the University of Minnesota.

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FOURTH ANNUAL SEED LABORATORY REPORT

By R. C. Dahlberg and W. L. Oswald

INTRODUCTION

During the year 1916-1917, 10,967 samples of seed were voluntarily sent in to the seed laboratory for testing as to purity or germination, or both. This represents an increase of approximately fifteen per cent over the number sent in during the preceding year. Figure 1 graphically depicts the number of samples received each year since the establishment of the seed-testing laboratory in 1909. These samples were received from both farmers and seedsmen. Most of them were sent in by farmers. The activities of the laboratory have been almost wholly confined to the analysis of these samples. The large number has made it impossible to carry on any organized seed inspection work. The educational feature of the work and the value of using only tested seed for planting has been emphasized whenever possible.

SOURCES OF SAMPLES

Table I shows the number of samples of seed sent in for testing by the various counties. Fully 60 per cent of these were received from farmers. The impetus given to seed-testing work by county agents is very apparent.

TABLE I

Samples Received, by Counties

Name	1913–14	1916–17	Name	1913–14	1916–17
Aitkin	63	123	Dodge	11	17
Anoka	31	27	Douglas	39	46
Becker	48	64	Faribault	38	67
Beltrami	6	17	Fillmore	32	72
Benton	2	12	Freeborn	85	268
Big Stone	15	338	Goodhue	96	248
Blue Earth	55	152	Grant	248	278
Brown	109	66	Hennepin	622	1439
Carlton	14	6	Houston	23	42
Carver	86	30	Hubbard	10	9
Cass	11	33	Isanti	23	42
Chippewa	24	144	Itaska	5	96
Chisago	41	101	Jackson	10	58
Clay	33	90	Kanebec	8	108
Clearwater	23	24	Kandiyohi	11	70
Cook	19	0	Kittson	10	88
Cottonwood	16	14	Koochiching	0	10
Crow Wing	43	89	Lac qui Parle	6	99
Dakota	55	83	Lake	0	0

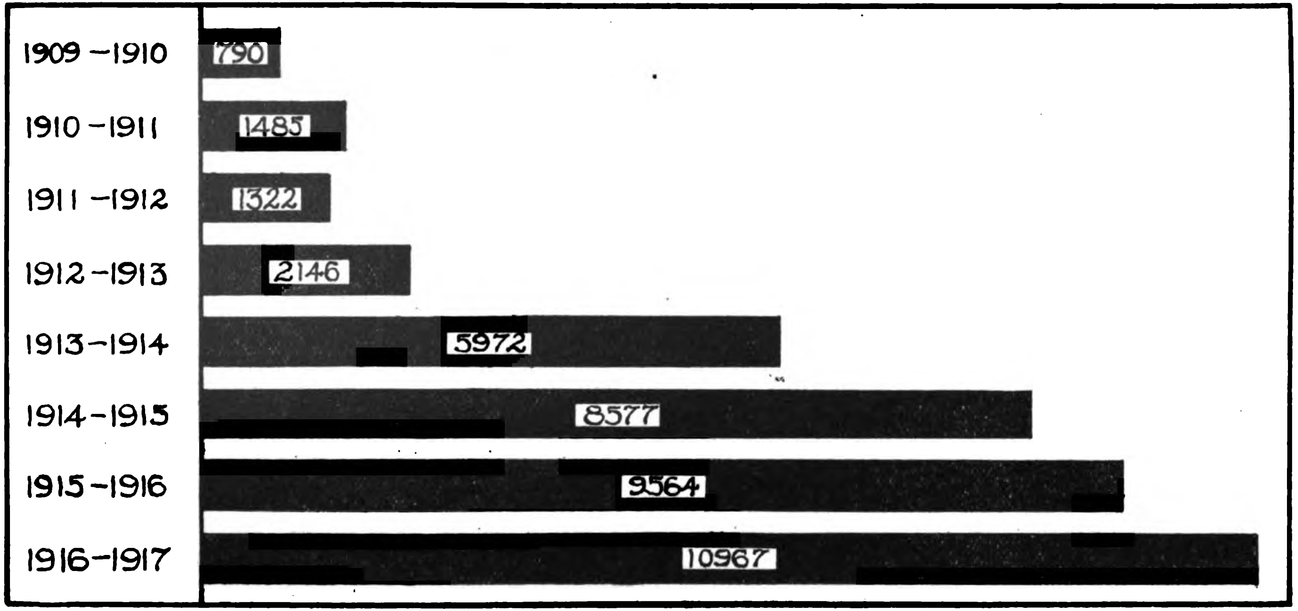

Fig. 1. Increase in Number of Samples Sent to Seed Laboratory

The seed law went into effect in 1913.

TABLE I—*Continued*

SAMPLES RECEIVED, BY COUNTIES

Name	1913–14	1916–17	Name	1913–14	1916–17
Le Sueur	26	45	Redwood	24	56
Lincoln	13	19	Renville	81	592
Lyon	33	77	Rice	267	497
McLeod	62	141	Rock	20	39
Mahnomen	0	10	Roseau	8	28
Marshall	45	139	St. Louis	54	94
Martin	26	33	Scott	22	25
Meeker	15	86	Sherburne	126	118
Mille Lacs	21	32	Sibley	18	37
Morrison	18	36	Stearns	54	105
Mower	26	17	Steele	175	217
Murray	14	24	Stevens	30	41
Nicollet	6	32	Swift	76	307
Nobles	12	41	Todd	22	65
Norman	22	97	Traverse	8	388
Olmsted	57	48	Wabasha	65	66
Otter Tail	136	197	Wadena	40	13
Pennington	35	70	Waseca	19	47
Pipestone	14	17	Washington	106	274
Pine	57	81	Watonwan	8	15
Polk	92	115	Wilkin	15	83
Pope	77	53	Winona	19	46
Ramsey	590	717	Wright	172	235
Red Lake	9	60	Yellow Medicine	42	124

In a few counties, notably Washington, Goodhue, Freeborn, Renville, Swift, Pipestone, and Traverse, well-organized testing campaigns were started by the county agents. In many of these cases the samples were obtained as a result of a campaign in which the school children cooperated. That such work creates a lasting impression is illustrated in the case of Grant County. During the year 1914-1915, because of the activity of the county agent, 962 samples of seed were received from this county for testing. The following two years were not characterized by any extraordinary activity on the part of the agent in regard to seed testing, nevertheless the number of samples sent in by Grant County in 1916-1917 was surpassed only by those counties in which seed companies were located, or in which special seed campaigns were instituted by the county agent.

INSPECTION WORK

Very little inspection work was carried on during the year 1916-1917, owing to the large number of samples voluntarily sent in for testing. Two complaints of improperly labeled seeds were investigated. A lot of red clover seed not properly labeled was sold at Roseau to go to the southeastern part of the state. Upon analysis it was found that it was not only not properly labeled, but that it contained seeds of both Canada thistle and perennial sow thistle, two very noxious and extremely serious weed pests. Prosecution was started and the seller was found guilty and penalized according to the provisions of the seed law. The southern part of the state is practically free from perennial sow thistle and the quantity of Canada thistle is also small in most localities. Every effort should be made to keep this part of the state as nearly free as possible from such noxious weeds.

The second complaint came from Hanley Falls. It concerned a mixture of alsike and timothy seed of very low quality which had been sold unlabeled by a seed company of Iowa doing a large mail order business in Minnesota on the basis of extensive advertisements in the farm papers. The seed was advertised at a very low price and was represented as high-class. Since such mail order sales were technically made in Iowa, it was impossible to enter legal proceedings against the company, the state law having jurisdiction only over sales made within the state. As an illustration of what a farmer may expect from such "cheap" seed the results of the analysis of this much advertised seed are given in detail. The farmer may judge for himself whether it pays to buy such seed.

ANALYSIS OF TIMOTHY AND ALSIKE

(Advertised at $4 per bushel)

Purity, 81.58 per cent—Alsike, 10.12 per cent; Timothy, 71.46 per cent.
Germination of Alsike clover, 44 per cent.
Germination of timothy, 84 per cent.

Weed Seeds Present in Sample

Ox-eyed daisy
Canada thistle
Perennial sow thistle
Wormseed mustard
Wormwood sp.
Five-stamened cinquefoil
Eragrostis grass
Smartweed
Prickly lettuce
Aster sp.
Small crabgrass
Motherwort
Yellow trefoil
Virginia plantain
White vervain
Knotweed
Beaked panicum
Black mustard
Wild barley
Heal-all
Barnyard grass
Catnip
Cyperus sp.
Avens sp.
Creeping spike rush
Bladder campion
Spotted spurge
Tumbling mustard
Cinquefoil
Evening primrose
Black-seeded plantain
Common plantain
Peppergrass
Wild peppergrass
Sheep sorrel
Mouse-ear chickweed
Brown-eyed Susan
Water hoarhound
Panic grass sp.
Mayweed
Buckthorn plantain
Low hop clover
Night-flowering catchfly
Smooth hawksbeard
Hare figwort
Spreading figwort
Rough pigweed
Tickle grass
Lamb's quarters
Shepherd's purse
Horsemint
Green foxtail
Lady's thumb
Bracted plantain

Legume sp.
Yellow wood sorrel
Northern bedstraw
Loosestrife
Round-leaved buttercup
Grass sp.
Spiny sow thistle
Reed meadow grass
Pinweed
Small-seeded false flax
Grooved yellow flax
Speedwell sp.
Dandelion
Pennyroyal
Blue vervain
Large crabgrass
Fireweed sp.
Mexican tea
Wild bergamot
Hedge mustard
Tall five-finger
Wood sage
Curled dock
Sleepy catchfly
Wintercress
Pink sp.
Blue vervain
Reed meadow grass
Canada milk vetch
Sandwort
Milkwort
Wild mustard
Saint-John's-wort
Common speedwell
Slender rush
Yarrow
Mullein
Forget-me-not
Blue lettuce
Cress

While the seed laboratory had no legal jurisdiction over this particularly flagrant case, vigorous action was taken with distinctly positive results. The seed laboratory, with the coöperation of the farm papers, made public through these papers the facts in the case as based upon the analysis. When this information was published, the advertising associations immediately took up the matter and suspended the guilty company from their advertising privileges for some time. The mail-order company, through its representative, after vainly trying to get the seed laboratory to retract the statements previously published, finally promised to send seed into the state only after complying with the labeling and sale regulations of the seed law. While no legal proceedings were possible, the net result was perhaps even more beneficial than the ordinary fine. The hearty coöperation of the farm papers in insisting on clean and honest advertising was especially helpful.

TESTS FOR PURITY

Table II gives the average percentage of purity of crop seeds for the year 1916-1917. The average purity for the preceding three years is also given for comparison. In the column headed "Samples too small for purity test," is noted the number of samples of each kind of seed which were so small that it was deemed inadvisable to make a purity test. The number of such samples was particularly large in the case of the cereals. It is impossible to obtain accurate, reliable, and representative results from a sample that is too small. Attention is called to the "Rules for Seed Testing" adopted by the Association of Official Seed Analysts of North America. A paragraph dealing with the size of sample reads as follows:

"The minimum weight of seed forwarded for test should be approximately:

"(a) One ounce of grass seed of any kind or of white and alsike clover.

"(b) Two ounces of red and crimson clover, alfalfa, millet, flax, or seed of like size.

"(c) One half pound of cereals or seed of like size."

In common terms, the quantity should range from a heaping single handful of the smallest seed to a heaping double handful of the cereals. It is a waste of time and energy to send in a sample that is too small for proper test.

TABLE II

SUMMARY OF PURITY TESTS FOR 1913-1914, TO 1916-1917

Kind of seed	Samples		Average purity	
	Number received 1916–17	No. too small for purity test 1916–17	1913–14 1914–15 1915–16	1916–17
			Per cent	Per cent
Alfalfa	294	29	96.7	96.38
Barley	406	115	96.1	94.9
Bluegrass, Kentucky	36	1	84.9	85.8
Brome grass	29	4	86.8	88.08
Buckwheat	49	10	97.8	98.58
Cane	23	16	97.4	97.5
Clover, alsike	150	4	91.0	92.0
Clover, red	1,461	58	92.96	95.35
Clover, crimson	1	0	98.5	98.72
Clover, sweet	54	1	94.56	96.47
Clover, white	31	1	91.13	90.34
Creeping bent grass	2	0	.....	74.65
Crested dog's tail	1	0	97.5	94.88
Emmer	17	6	95.19	89.03
Flax	127	17	95.9	94.13
Fescue	12	1	95.1	96.27
Johnson grass	1	0	.....	95.13
Lawngrass	16	0	87.9	89.9
Millet	220	5	95.73	95.15
Oats	562	254	97.63	95.63
Orchard grass	4	0	88.1	83.48
Ryegrass, Italian	2	0	95.3	93.98
Ryegrass, perennial	9	1	97.5	98.1
Rape	21	1	99.6	99.84
Redtop	46	0	84.8	84.18
Rye	37	16	97.0	97.14
Slender wheat grass	11	3	89.77	93.34
Sudan grass	9	2	98.67	96.02
Timothy	819	18	96.0	95.0
Vetch	9	3	98.03	97.9
Wheat	824	373	95.83	96.14

GERMINATION TESTS

Approximately ten thousand six hundred samples of seed were tested for germination during the year. The results are given in Tables III to VI, inclusive. The average germination for 1916-1917 is given in the second column and may be compared with the average germination for the preceding three years, given in the first column. In the case of the clovers, Table III, the percentage of germination was somewhat lower for 1916-1917 than the average for the preceding years.

The cereals of the crop of 1916-1917, Table IV, all proved to be lower in germination than those of the three years previous, especially the wheat. This was due entirely to the rust and drought at the close of the growing season.

The vegetable seed, Table VI, it will be noted are all rather low in germination. Fresh vegetable seed are not ordinarily so low in percentage of germination as indicated. Many samples of old seed are, however, received for testing each year and this tends to bring down the average.

TABLE III

GERMINATION TESTS OF ALFALFA AND CLOVERS FOR 1913-1914 TO 1916-1917

Kind of seed	Samples received 1916–17	Average germination		Hard seeds	
		1913–14 1914–15 1915–16	1916–17	1913–14 1914–15 1915–16	1916–17
		Per cent	Per cent	Per cent	Per cent
Alfalfa	327	76	70	17	21
Clover, alsike	246	81	74	13	15
Clover, red	1,545	80	77	13	15
Clover, crimson	1	78	83	2	0
Clover, sweet	62	50	63	35	24
Clover, white	38	76	73	18	20

TABLE IV

GERMINATION TESTS OF GRAIN AND FORAGE CROP SEEDS FOR 1913-1914 TO 1916-1917

Kind of seed	Samples received 1916–17	Average germination 1913–14 1914–15 1915–16	Average germination 1916–17
		Per cent	Per cent
Barley	586	91	88
Bluegrass, Kentucky	51	57	68
Brome grass	28	73	72
Buckwheat	60	89	92
Corn (field)	1,220	91	86
Creeping bent grass	2	68	62
Crested dog's-tail	1	63	55
Emmer	23	89	80
Fescue	15	69	69
Flax	147	87	85
Mangel	51	63	67
Millet	245	77	78
Oats	875	89	88
Orchard grass	4	49	64
Peas, field	9	56	89
Rape	32	89	92
Redtop	47	79	85
Rye	109	83	75
Rye grass, Italian	...	59	..
Rye grass, perennial	24	76	73
Slender wheat grass	3	81	73
Sorghum and amber cane	44	70	71
Soy bean	1	82	23
Sudan grass	11	86	76
Timothy	966	87	86
Vetch	12	69	71
Wheat	1,337	88	79
Wood meadow grass	...	75	..

TABLE V

GERMINATION TESTS OF HERBS FOR 1913-1914 TO 1916-1917

Kind of seed	Samples received 1916–17	Average germination 1913–14 1914–15 1915–16	Average germination 1916–17
		Per cent	Per cent
Caraway	1	49	9
Cress	4	31	33
Dill	11	34	26
Lavender	3	14	15
Sage	8	49	28
Savory	6	28	20
Thyme	4	36	30
Miscellaneous	24	37	49

TABLE VI

GERMINATION OF VEGETABLE SEEDS FOR 1913-1914 TO 1916-1917

Kind of seed	Samples received 1916–17	Average germination	
		1913–14 1914–15 1915–16	1916–17
		Per cent	Per cent
Asparagus	11	68	56
Bean	108	89	81
Beet	123	65	70
Brussels sprouts	6	42	70
Broccoli	4	48	77
Cabbage	128	67	54
Carrot	91	57	51
Cauliflower	20	73	59
Celeriac	7	..	62
Celery	47	58	51
Citron	7	74	74
Collard	...	65	..
Cucumber	72	80	75
Egg plant	14	52	41
Endive	15	73	47
Gourd	11	69	74
Ground cherry	2	23	63
Kale	11	25	67
Kohl-rabi	12	60	47
Leek	6	47	33
Lettuce	128	77	74
Muskmelon	114	76	73
Okra	8	54	51
Onion	167	68	52
Parsley	29	47	41
Parsnip	27	34	36
Pea	150	56	76
Pepper	39	47	53
Potato	1	51	0
Popcorn	5	84	85
Pumpkin	45	66	73
Radish	136	73	72
Rhubarb	7	45	70
Rutabaga	28	77	63
Salsify	9	63	68
Spinach	71	54	60
Squash	45	72	73
Sweet corn	109	81	79
Swiss chard	2	75	66
Tomato	106	72	77
Turnip	57	80	61
Watermelon	69	70	71

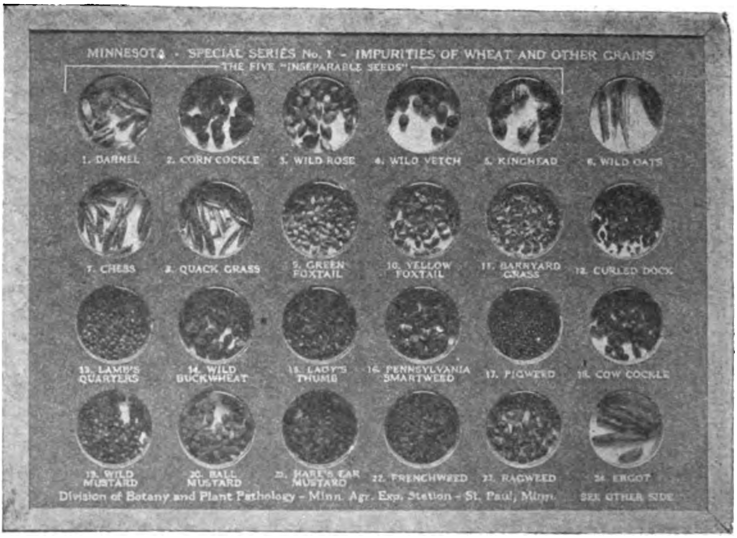

Fig. 2. Minnesota Weed Seed Case, Special Series No. 1.

PUBLICATIONS OF THE SEED LABORATORY

The following publications have been issued by the seed laboratory and will be mailed on request to the Office of Publications, University Farm, St. Paul:

Farmers' Library Bulletin No. 24—Seed Testing.
Farmers' Library Bulletin No. 39—Minnesota Seed Law.
Bulletin No. 129—Minnesota Weeds, Series I.
Bulletin No. 139—Minnesota Weeds, Series II.
Bulletin No. 147—First Annual Seed Laboratory Report, 1913-14.
Bulletin No. 159—Second Annual Seed Laboratory Report, 1914-15.
Bulletin No. 165—Third Annual Seed Laboratory Report, 1915-16.

Farmers' Library bulletin No. 39, dealing with the Minnesota seed law, should be in the hands of every person who sells agricultural seed for seeding purposes. It contains much pertinent and necessary information relating to the sale of agricultural seed.

The seed laboratory has also issued a new weed seed case, Minnesota Weed Seeds, Special Series No. 1 (Figure 2). This case contains the "inseparable weed seeds" mentioned in the former federal grades for wheat, besides other seeds very commonly found in wheat and other cereals. This seed case should be of interest to all dealers in grain. It can be obtained at cost by addressing the Seed Laboratory, University Farm, St. Paul, Minnesota.

7633.45

BULLETIN 176 JULY 1918

The University of Minnesota

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AGRICULTURAL EXPERIMENT STATION

MINNESOTA WEEDS

SERIES III

DESCRIPTIONS AND IDENTIFICATIONS

BY

W. L. OSWALD

DIVISION OF PLANT PATHOLOGY AND BOTANY

AND

ERADICATION

BY

ANDREW BOSS

DIVISION OF AGRONOMY AND FARM MANAGEMENT

UNIVERSITY FARM, ST. PAUL

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MINNESOTA WEEDS, SERIES III

By W. L. Oswald and Andrew Boss

INTRODUCTION

The Seed Laboratory of the Division of Plant Pathology and Botany has prepared four seed cases, each containing the seeds of twenty-four different weeds.[1] This bulletin describes the weeds of seed case Series III (see Figure 1).

Bulletins 129 and 139, describing the weeds whose seeds appear in seed cases I and II, may be obtained by applying to the Office of Publications, University Farm, St. Paul, Minn. A general discussion of weeds appears in Bulletin 129. In these bulletins the authors have not adhered to a strictly botanical terminology but have used largely the language of the farm and seed trade in order to avoid confusion and to make the bulletin practical for farm use. This is especially true in regard to the term "seed" which is frequently used for structures which are, in the strict botanical sense, fruits.

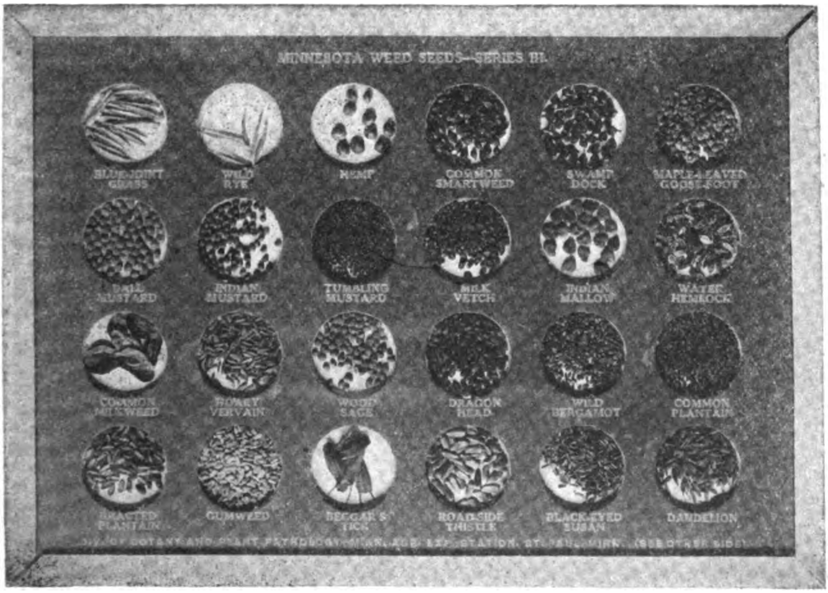

Fig. 1. Minnesota Weed Seed Case Series III

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[1] The seed cases may be obtained from the Seed Laboratory, University Farm, St. Paul, Minn., at cost. Four cases, each containing twenty-four kinds of weed seeds, are now available.

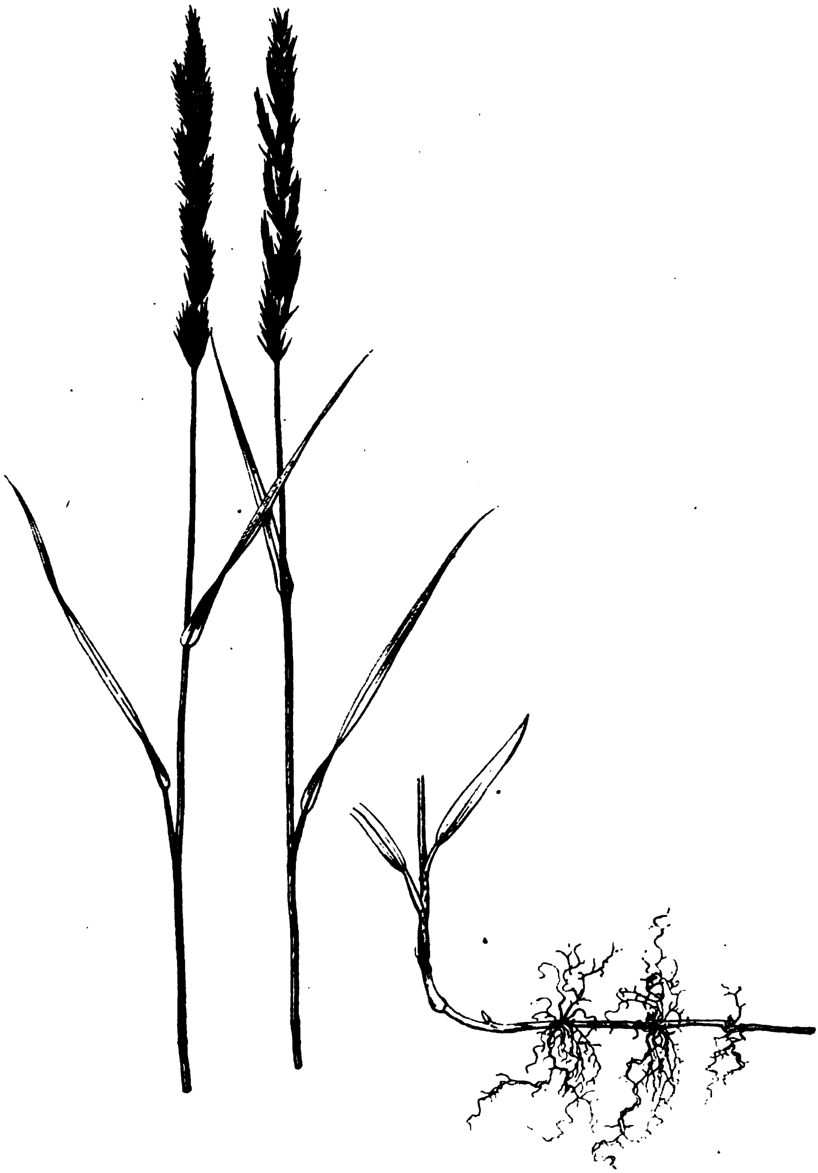

Fig. 2. Blue Joint Grass

INDIVIDUAL WEEDS

Blue Joint Grass (*Agropyron smithii* Rydb.)

Other common names.—Western wheat grass, western couch grass, Colorado bluestem.

Description.—Western wheat grass is a perennial which is very closely related to quack grass, but is not, however, considered a very serious weed pest. It is becoming quite common throughout the state. This grass grows quite abundantly in the western states, especially on alkali soil, and is considered a fairly good forage grass. The leaves are rough and very rigid and have a bluish green color by means of which patches of western wheat grass can usually be readily distinguished from other grasses. It spreads by both seeds and underground stems. The straw-colored seeds, which mature in July and August, are very similar to those of quack grass and can be distinguished only when the seeds are carefully examined under a powerful lens. The seeds of western wheat grass are often found in the commercial brome grass, alfalfa, timothy, and red clover seed.

Eradication.—Western wheat grass is not hard to eradicate and is usually considered a desirable forage plant rather than a weed. It yields readily to cultivation, and cropping the land to grain or cultivated crops will subdue it in nearly all types of soil. Seed formation should, of course, be prevented to avoid reseeding where not wanted.

Nodding Wild Rye (*Elymus canadensis* L.)

Other common names.—Wild rye, lyme grass, bunch grass (British Columbia), rye grass.

Description.—Nodding wild rye is a perennial grass common throughout the state, and grows equally well in sandy, black, or clay soil. It is usually from two to three feet high and has stout nodding spikes from four to six inches long with long, wavy awns. These awns are sometimes injurious to grazing animals, penetrating the ears, eyes, and nostrils. The root system is fibrous and there are no long underground stems. The plant spreads chiefly by its seeds which, however, are seldom found in any commercial seed except that of brome grass, in which it is often found.

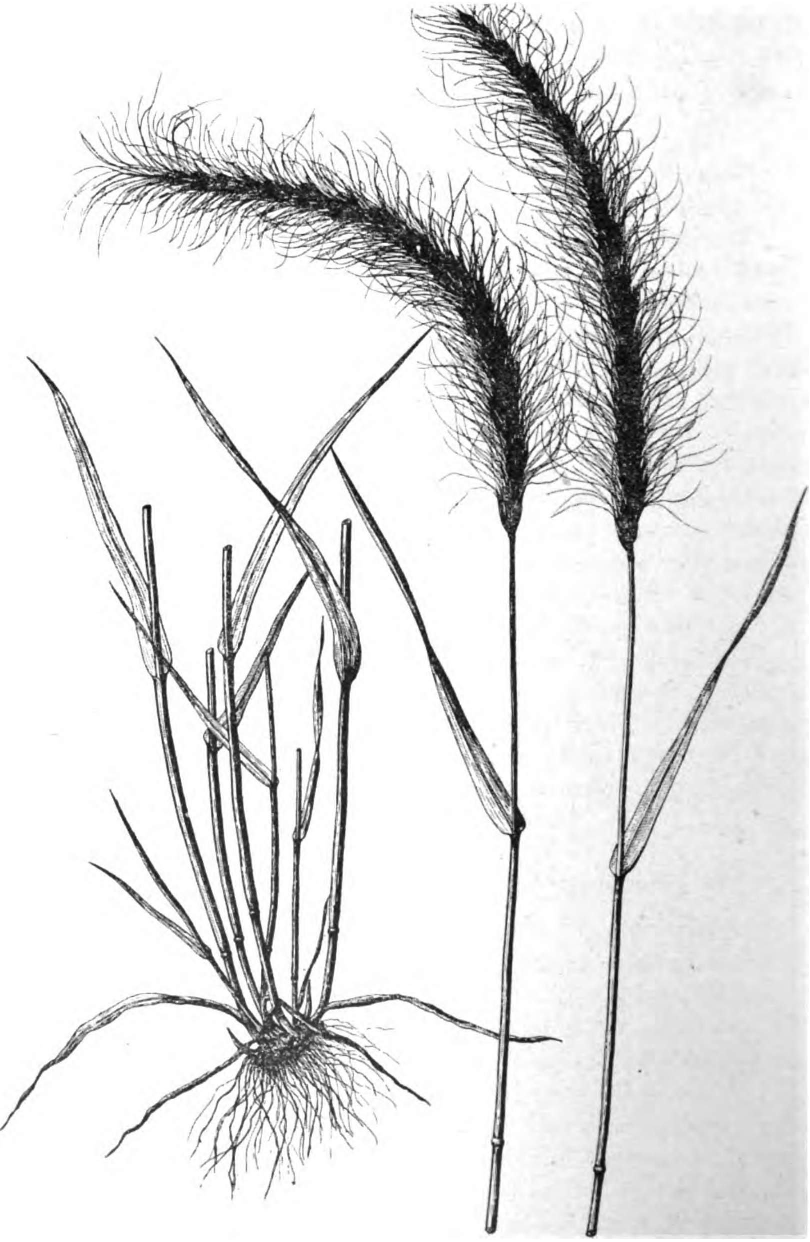

Fig. 3. Nodding Wild Rye

Eradication.—Stray plants of nodding wild rye may be pulled and destroyed before seeds set. If a field is badly infested, which is not often, the plants should be cut for hay when first headed out and the land plowed and cropped for a year or two.

Hemp (*Cannabis sativa* L.)

Other common names.—Carl hemp, fimble, callow-grass.

Description.—Hemp is a weed in barnyards, waste places, along roads and river banks, and also in cultivated fields. It is an annual plant from three to ten feet high and is very rough and hairy and strongly scented. The stout upright stem has a tough inner bark containing strong fibers for which the plant is often cultivated. It blossoms from July to September, the seeds ripening from August to November. It is propagated only by seed. The grayish oval seed are fed to caged birds. Hemp seeds are seldom found in commercial seed except oats and then only when the oats are from a hemp-growing district.

Eradication.—Wild hemp is not difficult to eradicate if the plants are prevented from seeding. Cutting the crop often enough to stop the formation of seed is the first step. Plowing waste places and seeding to more desirable crops, thus occupying the land, is the second step. Plowing land that has grown wild hemp and planting a cultivated crop, hoeing where necessary to remove stray plants, is usually most effective.

Common Smartweed (*Polygonum hydropiper* L.)

Other common names.—Water pepper, biting knotweed.

Description.—Smartweed is an annual plant growing in moist or wet locations and is commonly found in barnyards, gardens, and waste places. It flowers from June to September and its time of seeding is from July to November. The leaves are quite narrow and are very acrid and peppery. It grows from ten inches to two feet tall and is light green to reddish in color. This plant spreads only by seeds and is not considered a bad weed pest in this state. The seeds of the common smartweed are dull brownish black in color, more or less three-sided and quite pointed at the apex, and are often found in commercial seed of red clover, alfalfa, millet, timothy, and flax.

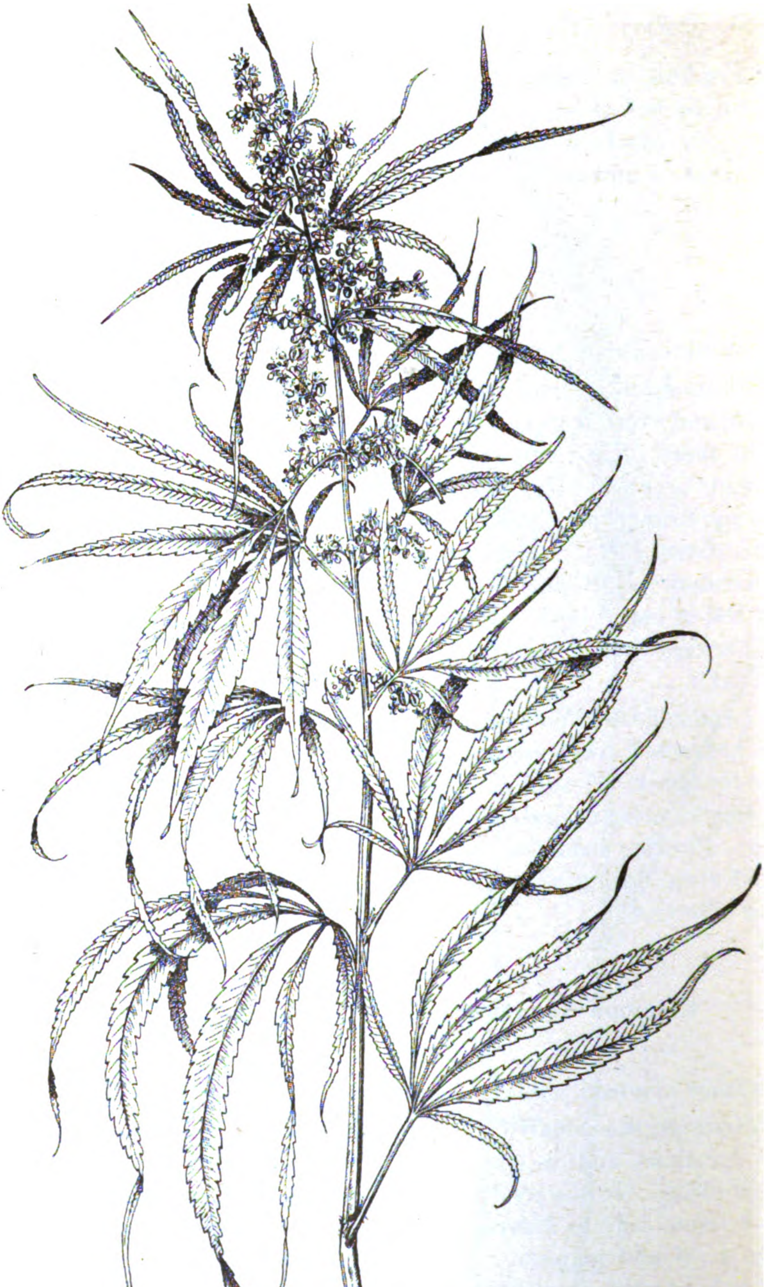

Fig. 4. Hemp

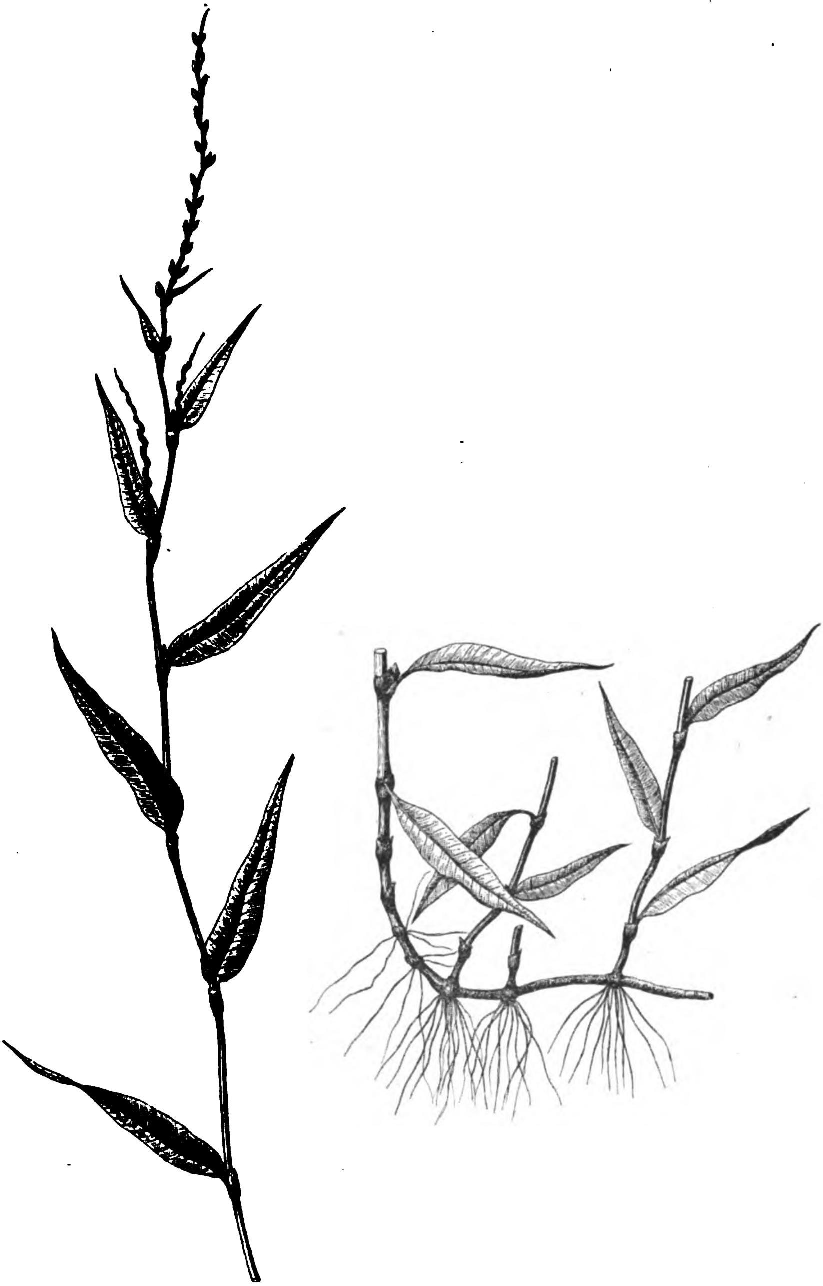

Fig. 5. Common Smartweed

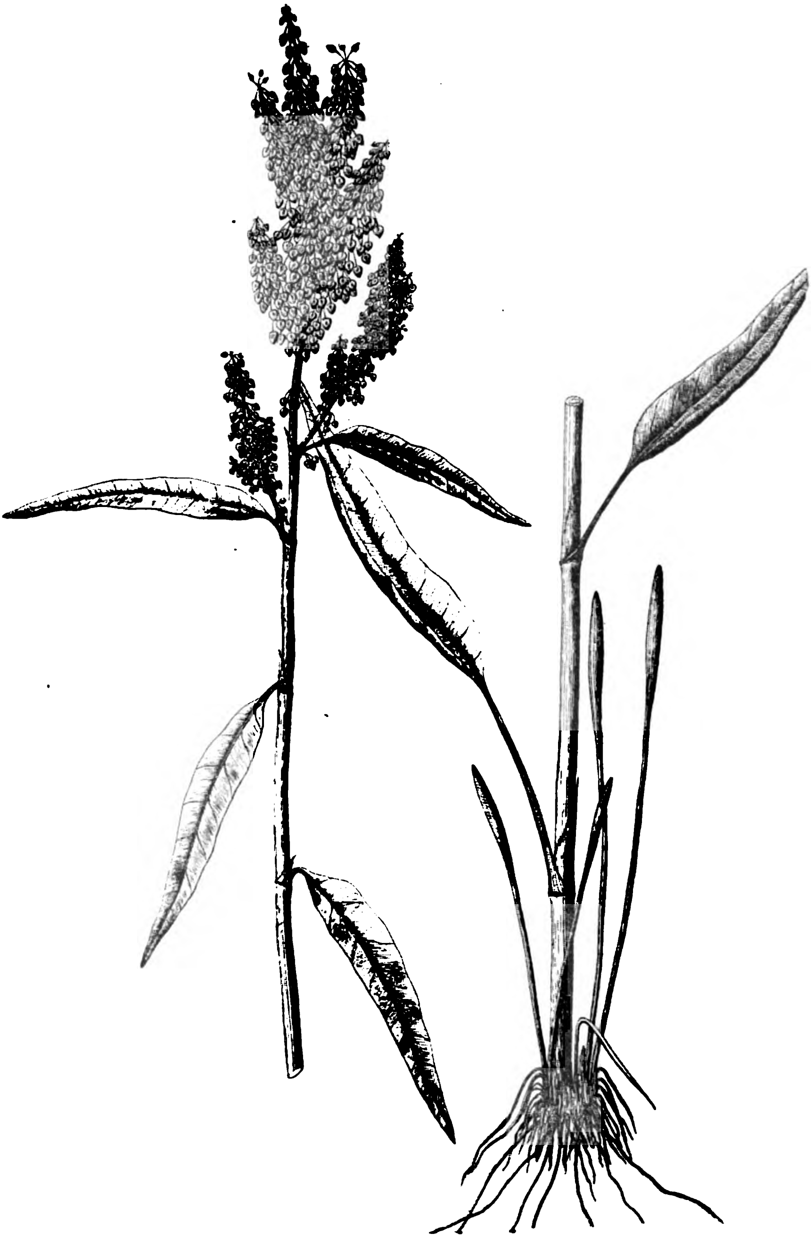

Fig. 6. Swamp Dock

Eradication.—Smartweed is not a troublesome weed in well-cultivated fields where the soil is in good condition. It yields readily to cultivation. Mow frequently to prevent seeding. Drain the land if low and wet. Keep the land occupied by other crops.

Swamp Dock (*Rumex verticillatus* L.)

Description.—Swamp dock, like curled dock, is a perennial but is not so widely distributed over the state as curled dock. It always grows in wet, swampy places, flowering from May to July and seeding from August to November. The leaves are narrowly oblong and of a pale greenish color. The lower leaves are often heart-shaped at the base. The plant has a stout grooved stem, and grows from two to five feet high. The reddish brown triangular seeds are very seldom found in commercial seed, appearing occasionally however, in the seed of red clover.

Eradication.—Remove stray plants of swamp dock by spudding or spading out. Drain and subdue the low land or swamps. Plow and crop the land and swamp dock will disappear.

Maple-Leaved Goosefoot (*Chenopodium hybridum* L.)

Description.—Maple-leaved goosefoot is an annual plant, flowering from July to September and seeding from August to November. It grows from two to five feet tall and is found most commonly in woods, thickets, and shady places, altho it is sometimes found along roadsides and in waste places. The thin leaves are small, triangular in shape, and resemble those of the common maple. The seeds resemble those of lamb's quarters, described in Series I,[2] but are larger and more uniform in shape. The seeds are often found in alfalfa, red clover, and timothy, and to some extent in alsike and millet.

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[2] Oswald, W. L. and Boss, Andrew. Minnesota weeds series I. Minn. Agr. Exp. Sta. Bull. 129. 1913.

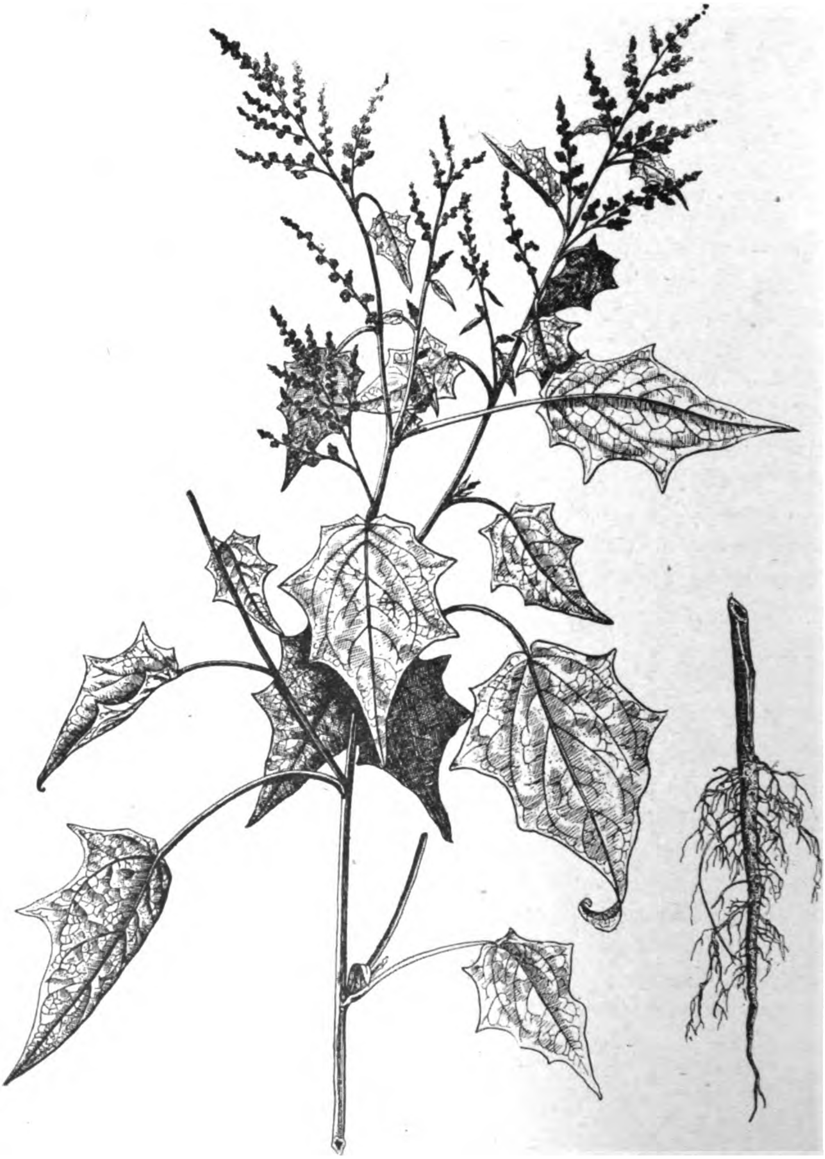

Fig. 7. Maple-Leaved Goosefoot

Eradication.—Cut or pull goosefoot before the seeds form. Keep the land fully occupied with more useful plants. It is not troublesome in well-cultivated fields.

Ball Mustard (*Neslia paniculata* (L) Desv.)

Other common names.—Yellow weed, neslia.

Description.—Ball mustard is generally an annual, altho it sometimes lives for two years. It flowers from June to September, and seeds from July to October. It grows from one to two feet tall and is generally found in grain fields and waste places. Only recently has it been found commonly distributed in this state. The flowers, about one eighth of an inch in diameter, are yellow and the leaves are lance-shaped, somewhat narrowed at the base. The stem leaves are arrow-shaped and clasping. There is generally but one seed in a pod. The seed pods, which cling very closely to the seed, are greenish brown in color and the surface is roughened by a network of veins. Ball mustard propagates only by seeds. The seeds are found most commonly in cereals, altho sometimes in clover and alfalfa seed.

Eradication.—Clean all seed grain thoroly. Disk the stubble in fields badly infested by ball mustard as soon as the crops are removed, to cover seeds and induce germination. Disk again later in the fall and plow. Sow to an early crop such as barley or sixty-day oats. If the mustard still appears in large quantities, cut before seeds form and cure with the barley or oats for hay. If only scattering plants appear, pull by hand, carry from field, and burn. As with other annuals, prevention from seeding will eventually bring eradication. A well-planned crop rotation which provides for one or two years in grass will help keep ball mustard in control.

Indian Mustard (*Brassica juncea* (L) Cosson)

Description.—Indian mustard is an annual or biennial plant and is propagated only by seed. It flowers from May to July and seeds from June to August, growing quite commonly in grain fields and along roadsides. It is very similar to the common mustard, which is widely distributed throughout this state. The pods of the Indian mustard are arranged more symmetrically than those of the common mustard. The plant grows from one to four feet tall and has rather stout but few branches. The bright yellow flowers are about half an

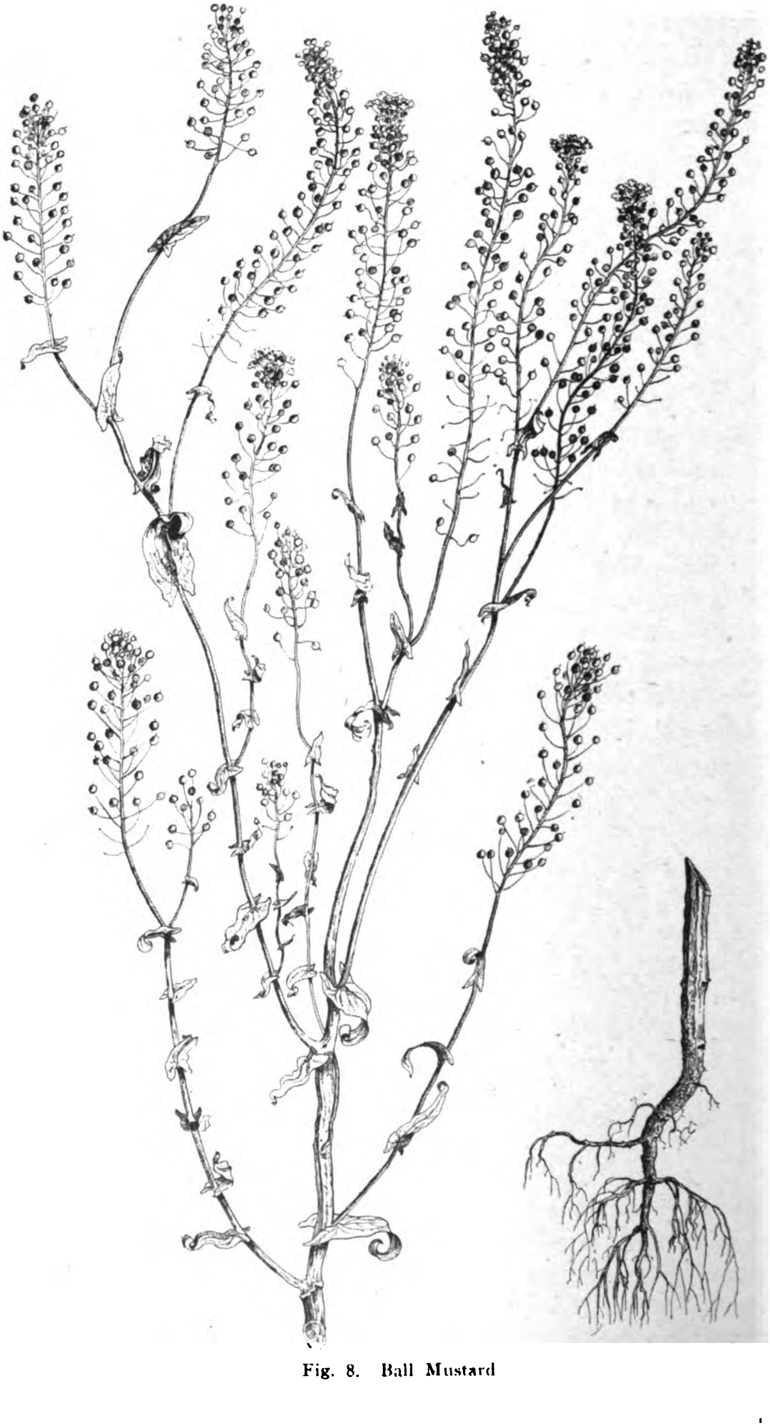

Fig. 8. Ball Mustard

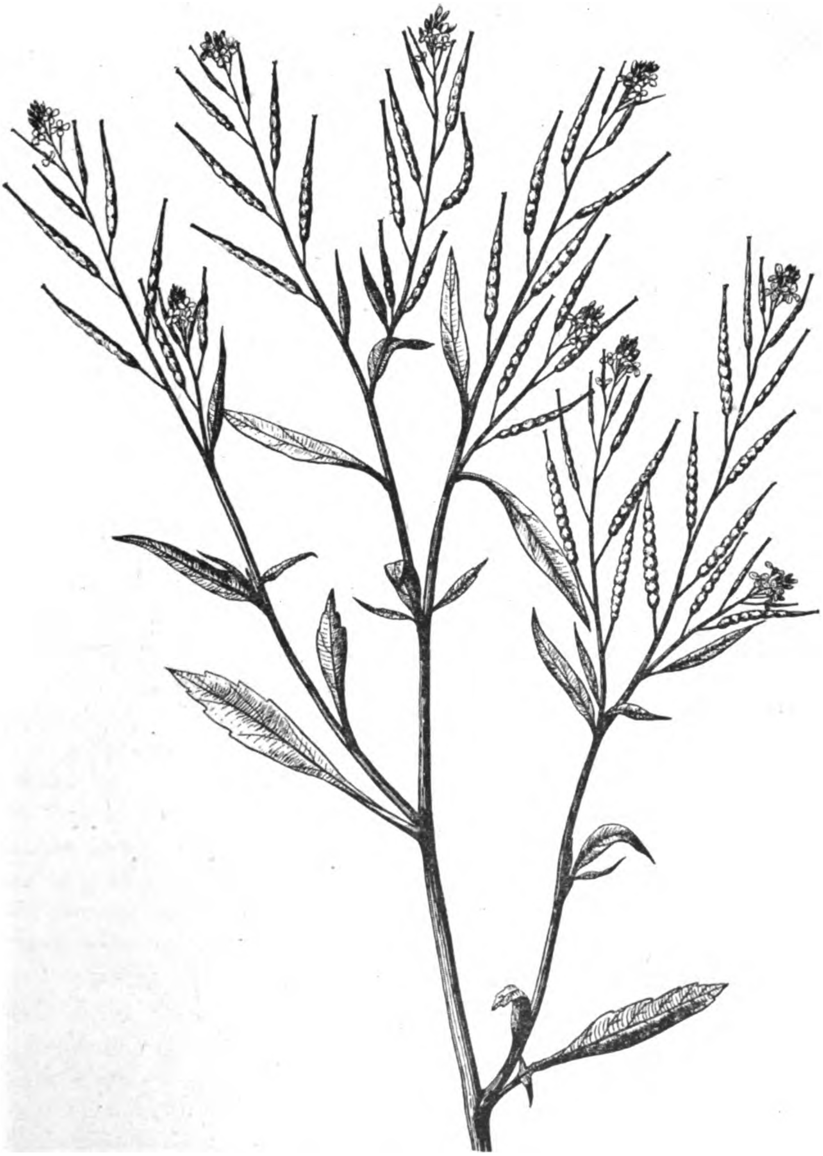

Fig. 9. Indian Mustard

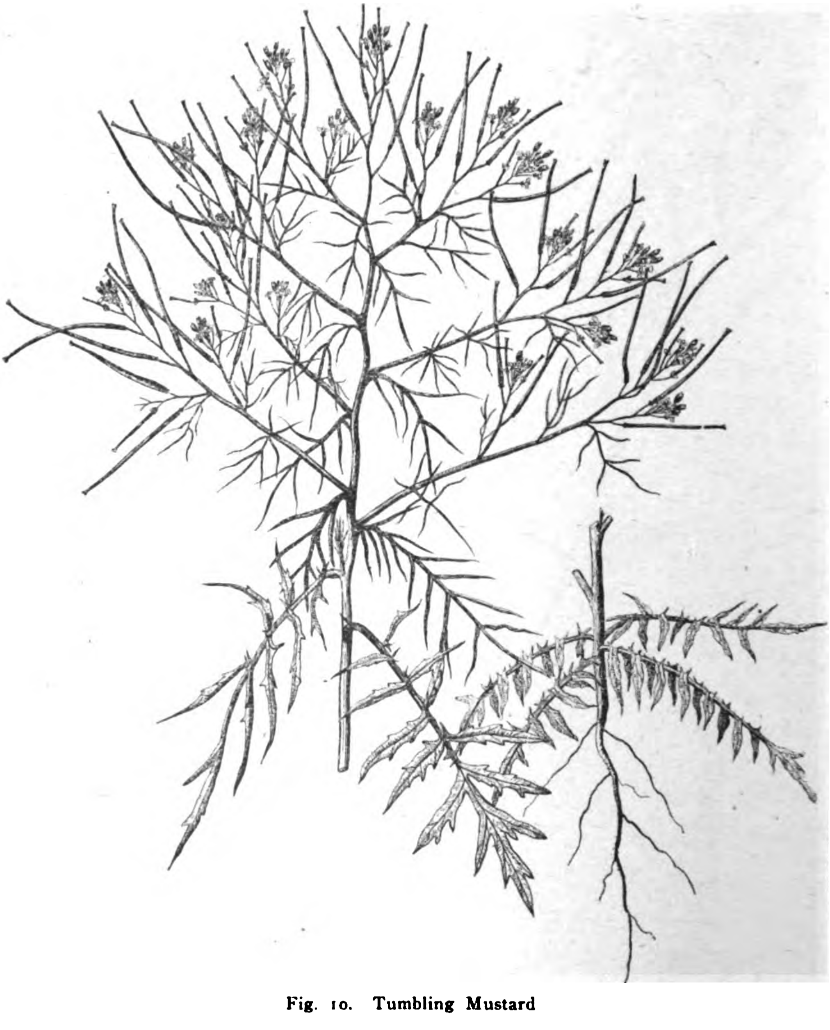

Fig. 10. Tumbling Mustard

inch broad and generally clustered at the top of the plant. The seeds are more or less spherical in shape and are dark reddish brown. The surface of the seed is marked by a network of veins which give it a honeycombed appearance. This, however, is not easily seen except with a magnifying glass. Indian mustard seed is found most commonly in the commercial seed of timothy, millet, red clover, alfalfa, flax, and cereals.

Eradication.—The same methods of eradication as are advised for ball mustard will be effective for Indian mustard.

Tumbling Mustard (*Sisymbrium altissimum* L.)

Other common names.—Tall sisymbrium, tumble mustard, white mustard.

Description.—Tumbling mustard is an annual or winter annual plant which blossoms from June to July and seeds from July until frost. It is most commonly found in grain fields, waste places, and along roadsides, and in some of the western states it is considered a very serious weed pest. It is a fairly bad pest in this state, but not nearly so troublesome as some of the perennial weeds. The plant grows from two to four feet high and is much branched and bushy. As soon as the seeds are ripe, the plant breaks away readily from its roots just above the surface of the soil and is tumbled about by the wind. In rolling along the seeds may be scattered, and in this way it becomes quite widely distributed, as it propagates only by seed. The flowers of the tumbling mustard are pale yellow or cream color and are about one quarter of an inch in diameter. The seed pods are very long and slender, often containing from one hundred to one hundred twenty small brown or greenish yellow seeds. When this plant is very abundant in grain fields it interferes with cutting and elevating in self-binders. The seeds of tumbling mustard are found most commonly in the commercial seed of timothy, white clover, and redtop.

Eradication.—Clean seed grain carefully and prevent any mustard plants from going to seed. Pull stray plants by hand, carry them from the field, and burn them. These weeds usually appear at the edges of fields or where recently burned over but may appear in grain crops. If so, cultivate early in the season with a weeder or light harrow and pull by hand.

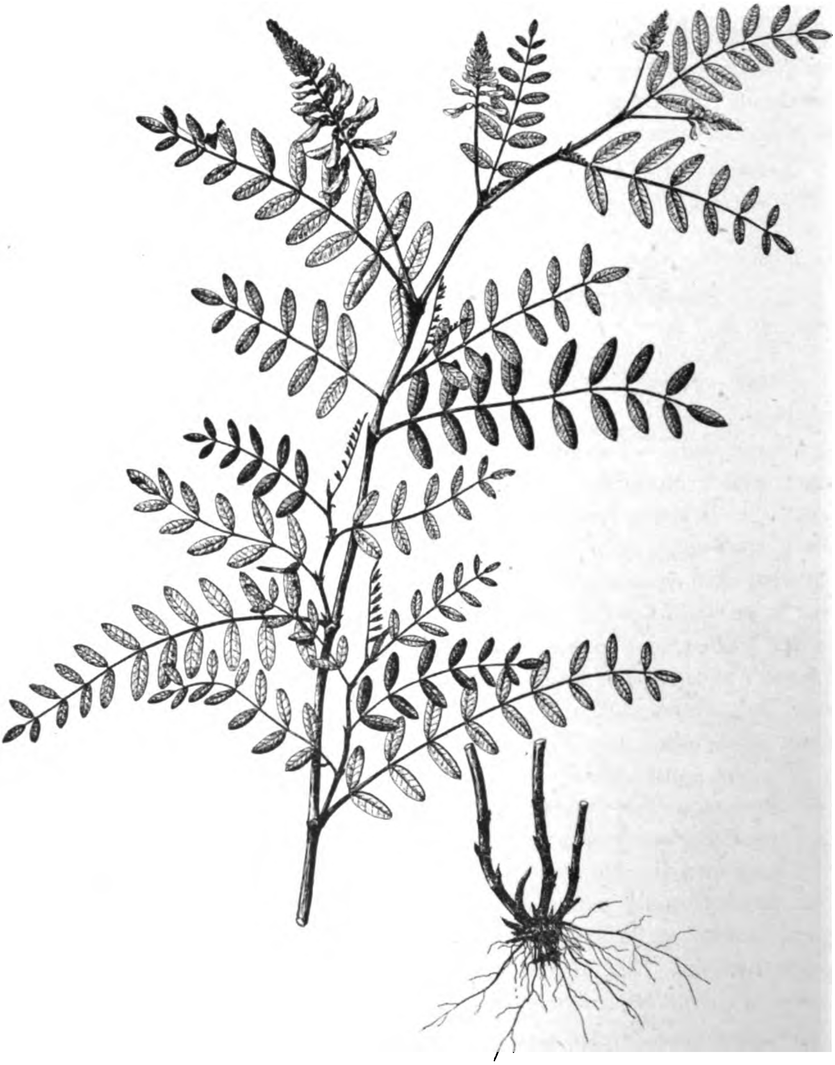

Fig. 11. Canada Milk Vetch

Canada Milk Vetch (*Astragalus canadensis* L.)

Other common name.—Canadian rattleweed.

Description.—Canada milk vetch, a perennial plant, grows from one to four feet high. It is propagated most commonly by seeds, which are yellow-green in color and more or less flat and kidney-shaped. It grows particularly well in dry gravelly soil and is often found along streams and in waste places and also in cultivated fields. It blossoms from July to August and seeds from August to November. The flowers are greenish yellow in color, very numerous, and clustered together in dense spikes. The leaves are compound, each being made up of from twenty-one to twenty-seven oblong leaflets. Seeds are occasionally found in the seed of red clover, timothy, and alfalfa.

Eradication.—Destroy the plants of Canada milk vetch before seeds form by mowing, pulling, or hoeing out. If fields are badly infested, plow and plant to a cultivated crop.

Indian Mallow (*Abutilon theophrasti* Medic.)

Other common names.—Velvet leaf, American jute, butter print.

Description.—Indian mallow is not a native plant. It grows particularly well in rich soil and is often found in waste places, farm yards, and vacant city lots. It is an annual weed, flowering from July to October and seeding from August to November. The plant generally grows from three to eight feet high and is very stout and somewhat branched. It has very large velvety, heart-shaped leaves from three to twelve inches broad, and on account of the velvety texture of the leaf the plant is often called velvet leaf. The large deep yellow, five-parted flower afterwards develops into a peculiar fruit made up of from twelve to fifteen hairy carpels with spreading beaks. The kidney-shaped seeds are grayish brown, one eighth of an inch long. They are seldom found in commercial seed.

Eradication.—Prevent seeding. Cut out all growing plants of Indian mallow before seeds mature. Practice good tillage and clean cultivation. Keep waste places occupied with grass or other crops.

Water Hemlock (*Cicuta maculata* L.)

Other common names.—Spotted cowbane, musquash root, beaver poison, muskrat weed, death-of-man, children's bane; also wrongly called water parsnip.

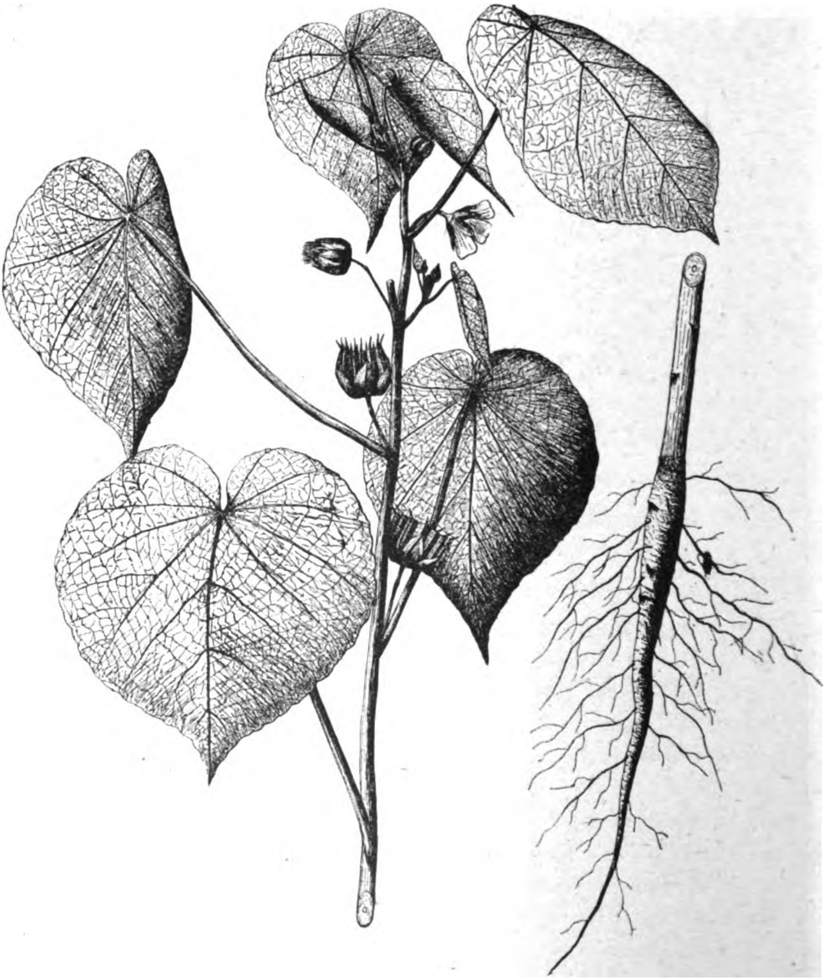

Fig. 12. Indian Mallow

Description.—Water hemlock is a perennial weed which grows almost entirely in wet meadows, marshy places, and along the sides of streams and ponds. The plants grow from three to six feet high. It is one of the few poisonous plants found in Minnesota. The root is particularly poisonous altho it has a pleasant aromatic taste. When it is eaten by cattle, death almost always follows. Persons have also been known to die from eating the root. Water in low places is often made poisonous by cattle crushing the roots. It blooms from July to August and seeds from August to October. The small, white flowers are formed in compound umbrella-like, many-flowered clusters from two to four inches across. Water hemlock is scattered almost entirely by seeds and by offsets from the crown of the root. The seeds are very seldom found in commercial seed.

Eradication.—Because of its poisonous nature and the danger to livestock, water hemlock should be destroyed wherever found. Spud or spade out or pull by hand after a rain, when the ground is soft. Prevent seed forming whenever possible. Drain and cultivate fields that are badly infested. When the fields are plowed and cultivated it is good practice to bring the roots to the surface with a spring-toothed harrow and gather and burn them.

Common Milkweed (*Asclepias syriaca* L.)

Other common names.—Silk weed, swallow-wort, silken cissy, cottonweed.

Description.—Milkweed is a perennial and is quite common throughout the state. It is often considered a very serious weed pest. It is particularly common in fields and pastures and in waste places, but it also often infests cultivated fields. The plant, which grows from two to five feet high, is propagated both by seeds and by root-stalks. The underground root-stalks are often hard to destroy. This makes the weed quite bad in cultivated fields. The opposite leaves are very thick and the under surface is covered with fine hairs. Both leaves and stem contain a thick milky juice. Milkweed flowers between June and August and seeds between August and October. The pinkish flowers are formed in dense nodding clusters and are very fragrant. The flat brown seeds are scattered particularly by the wind, owing to a tuft of fine silken hairs at the end of each seed.

Eradication.—Prevent milkweed from seeding by cutting the plants early. Practice good plowing and clean cultivation, prepare the land well, and make full seedings of all crops. Top-dress pastures and encourage full stands of grass.

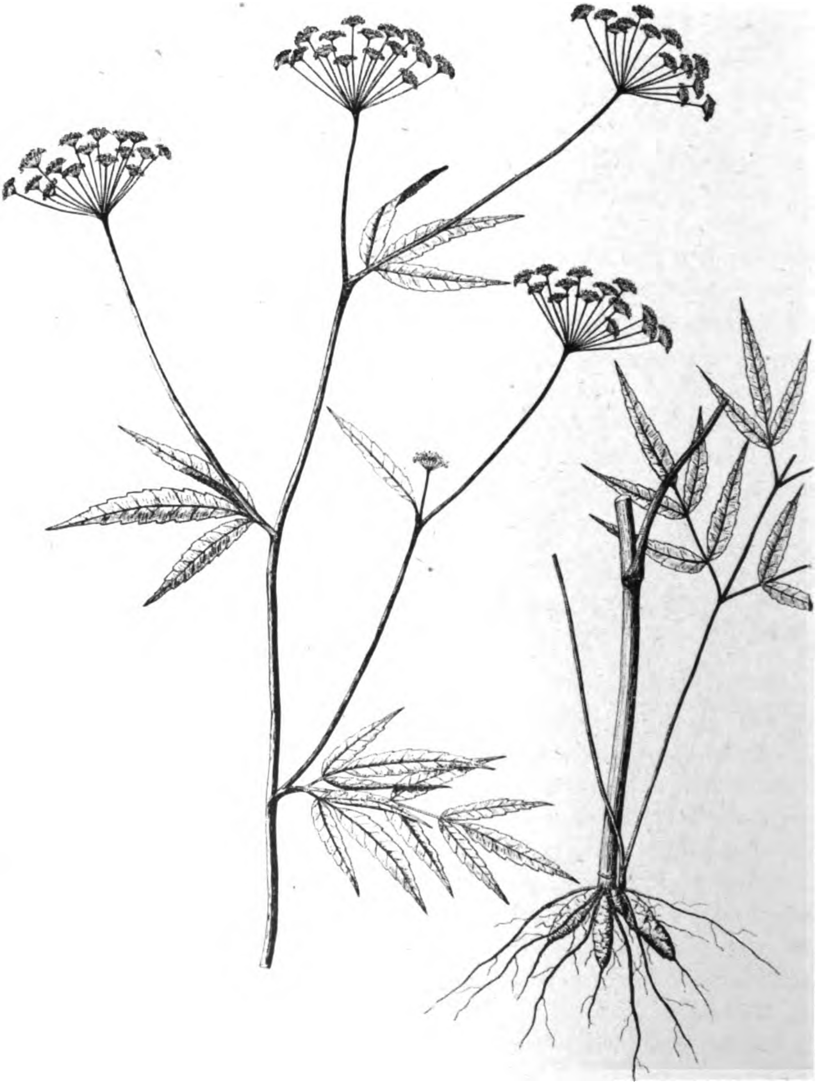

Fig. 13. Water Hemlock

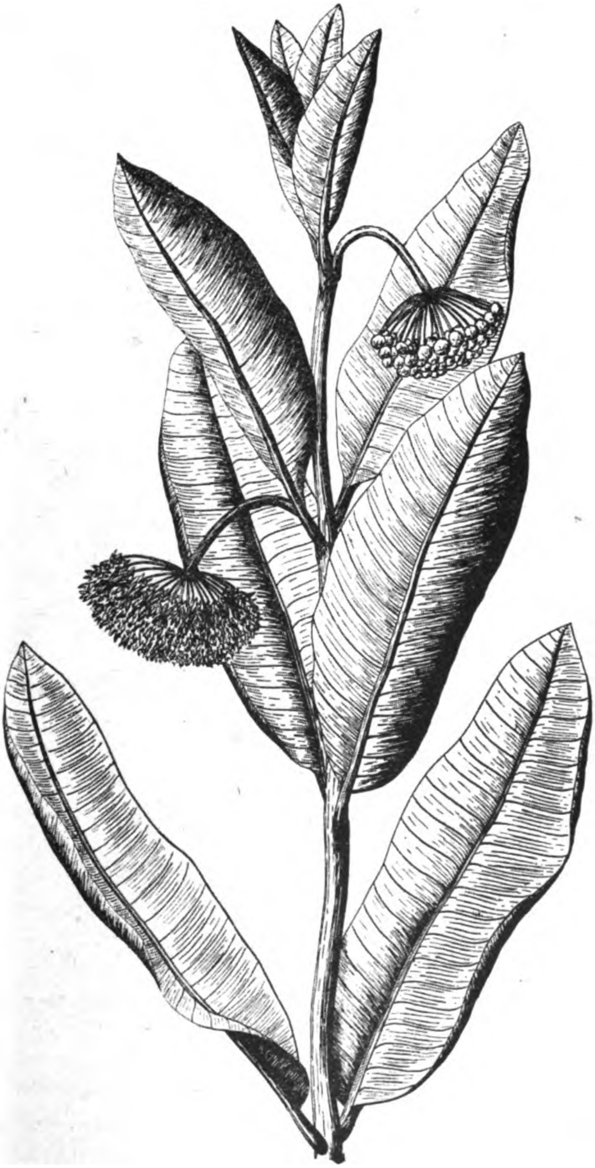

Fig. 14. Milkweed

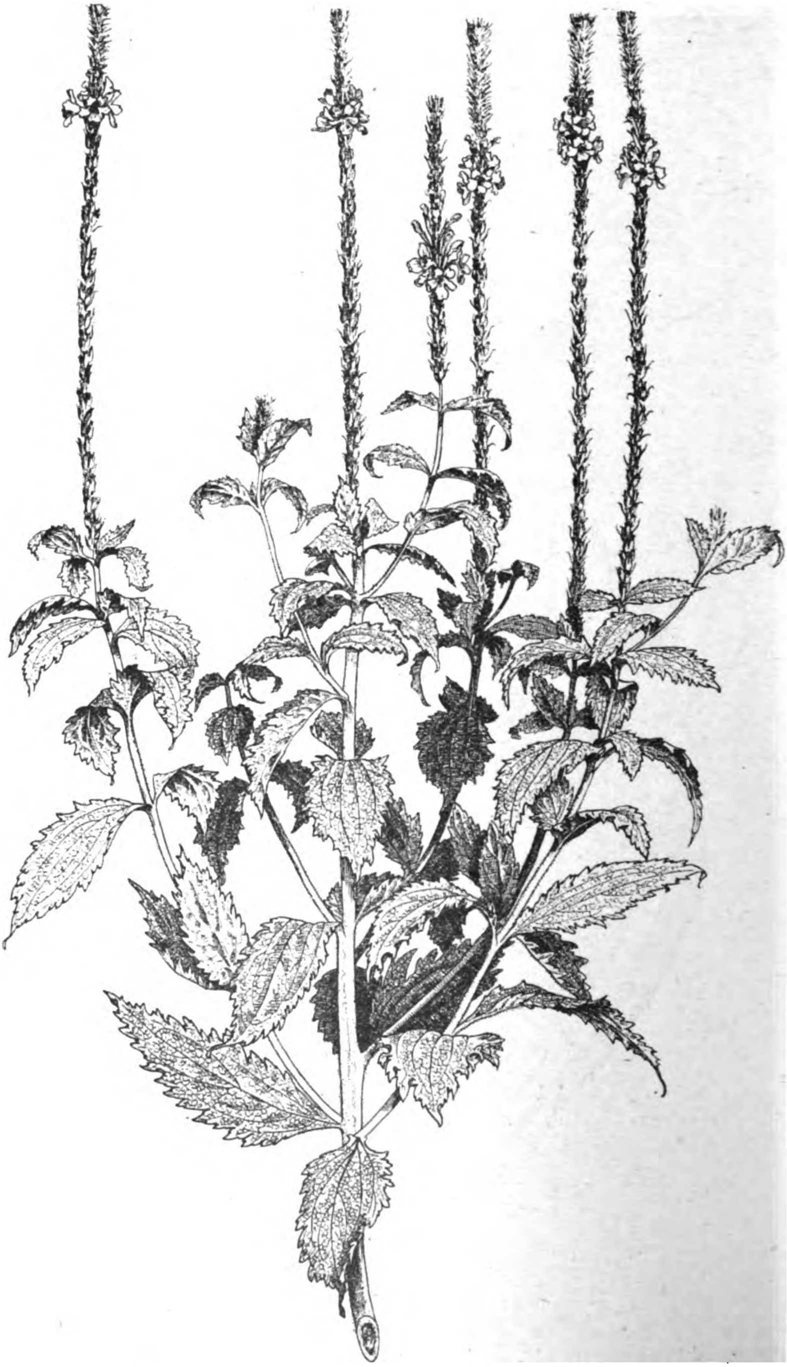

Fig. 15. Hoary Vervain

Hoary Vervain (*Verbena stricta* Vent.)

Other common names.—Wooly vervain, mullein-leaved vervain.

Description.—Hoary vervain is a perennial weed from two to four feet high, which flowers from June to September and seeds from August to November. It is seldom found in cultivated fields but is quite common on dry plains and prairies. The purplish flowers are borne on a dense solitary club-shaped spike between six and twelve inches long. The flowers at the bottom of the spike open first. The oblong reddish-brown seeds are often found in the commercial seed of red clover, timothy, alfalfa, and lawn grass. This plant is spreading slowly by its seeds being carried in hay.

Eradication.—Be careful to sow no grass seed containing seeds of hoary vervain. Cut grass crops early to prevent seeds from maturing. Spud out occasional plants when found.

Wood Sage (*Teucrium canadense* L.)

Other common names.—American germander, ground pine.

Description.—Wood sage is a perennial plant, flowering from June to September, and seeding from August to November. It lives on rich, low grounds, along roadsides, and on the banks of streams. This plant belongs to the Mint family, and grows from one to three feet high. It is not very much branched. It propagates only by seeds. The seeds are ovoid in shape, brown and rough, and are generally found in commercial seeds of timothy, millet, barley, red clover, oats, flax, and white clover.

Eradication.—Avoid sowing grass seed containing weed seeds. Spud out stray plants and plow and subdue badly infested spots.

Dragonhead Mint (*Dracocephalum parviflorum* (Tourn.) L.)

Other common name.—Dragonhead.

Description.—Dragonhead mint grows from four inches to two and one-half feet high. It is either an annual or a biennial and flowers from early June to August. The seeds mature early in the fall. It generally grows in rocky or gravelly soil, and is quite commonly distributed throughout the state. The pinkish white flowers are all crowded in a dense terminal head and the seeds, by means of which

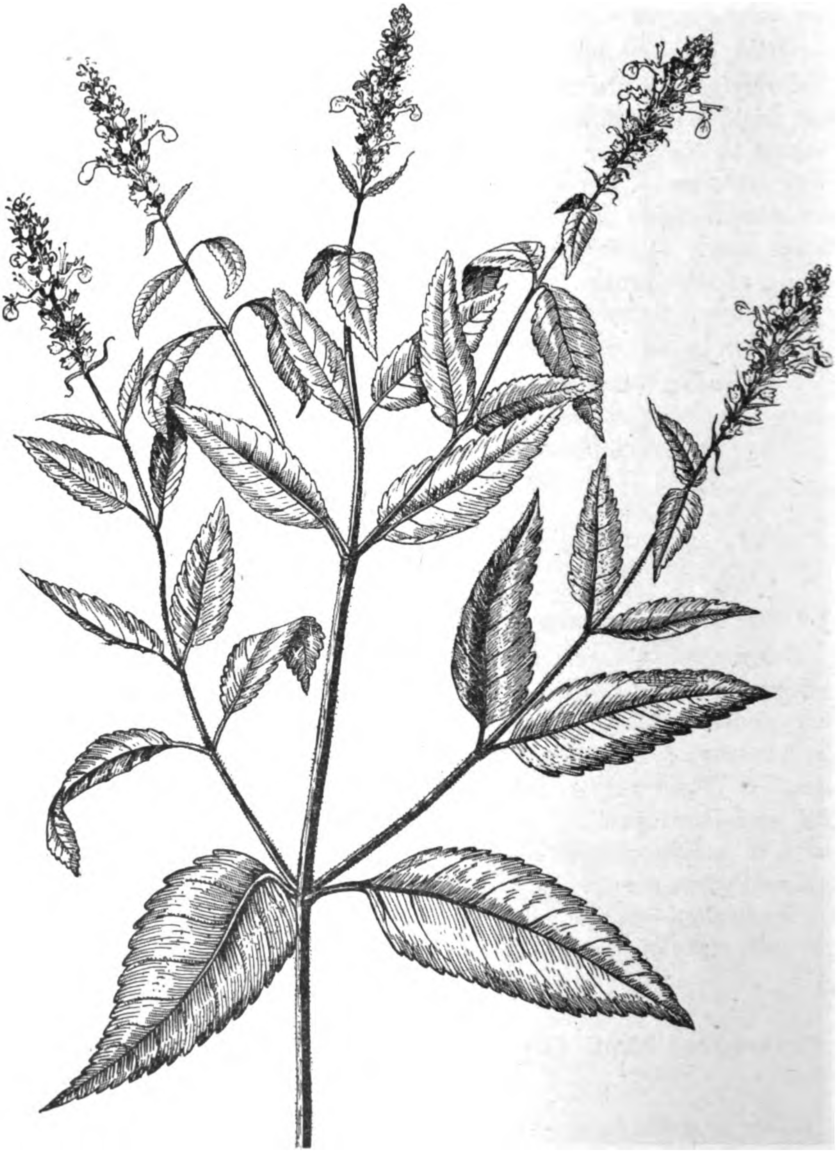

Fig. 16. Wood Sage

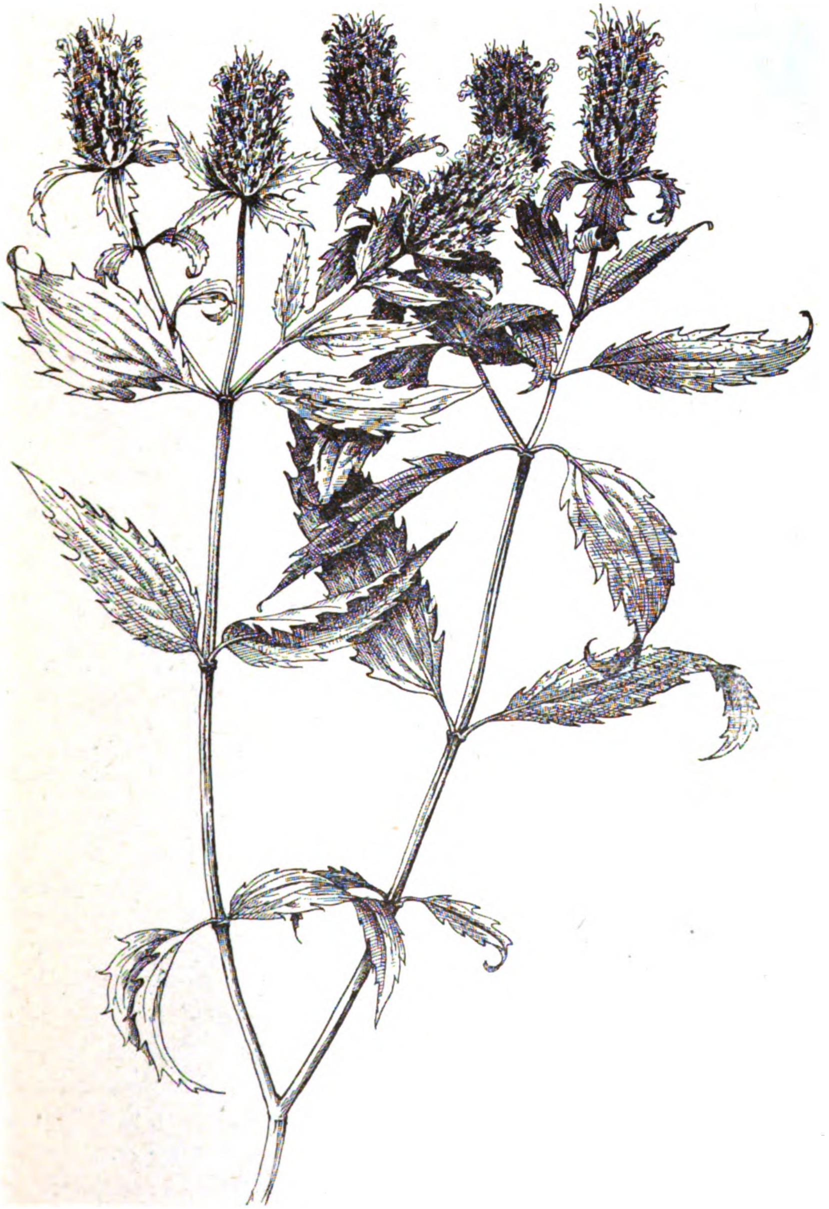

Fig. 17. Dragonhead Mint

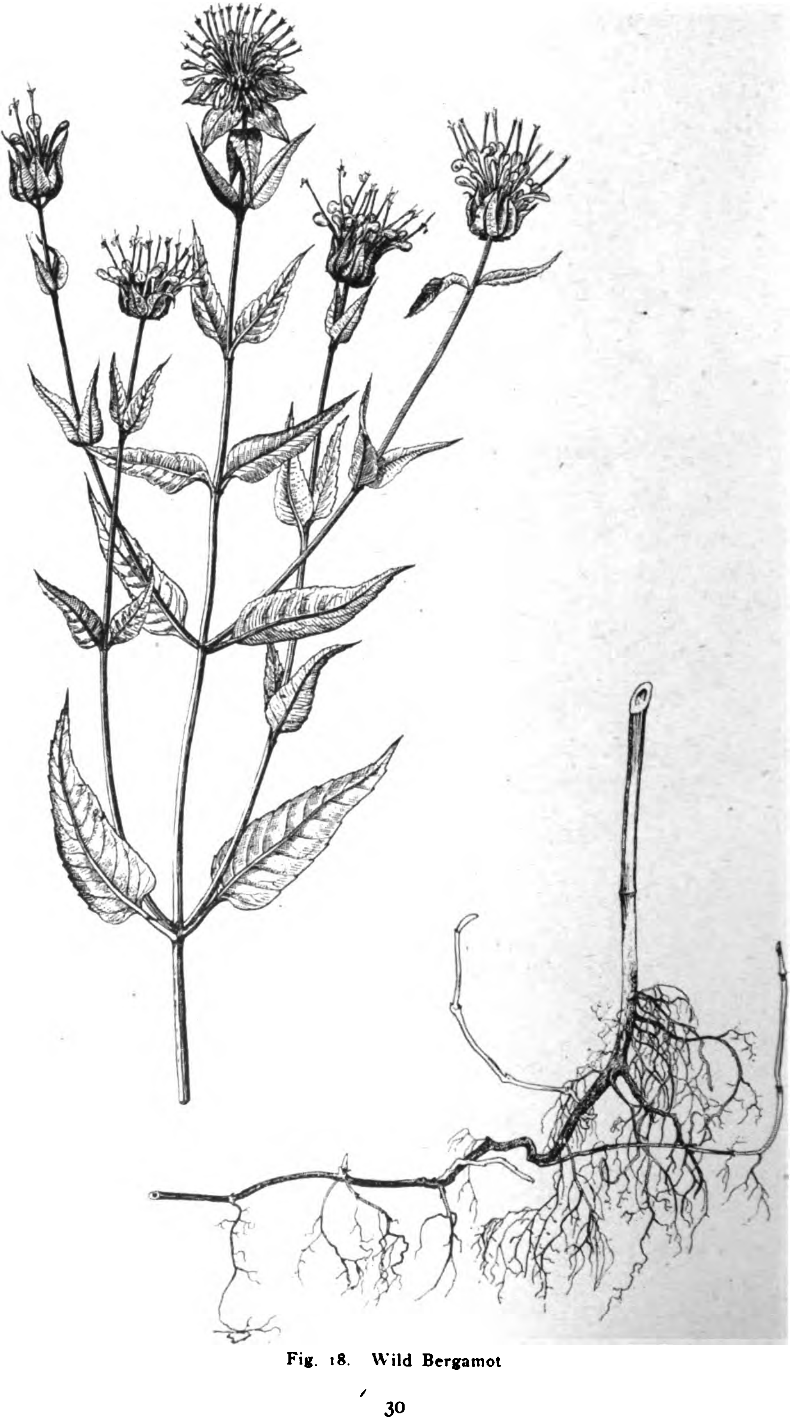

Fig. 18. Wild Bergamot

the plant is distributed, are black or blackish brown; about twice as long as wide; and three-sided, two sides being flat and the other side curved. They are often found in commercial seed of red clover, timothy, alsike clover, wheat, oats, and alfalfa, and sometimes in flax.

Eradication.—Sow only clean grain. Have grass seed examined for purity before sowing. Pull or spade out all plants.

Wild Bergamot (*Monarda fistulosa* L.)

Other common names.—Oswego tea, horsemint.

Description.—Wild bergamot is a perennial plant generally found in open woods and thickets and on dry rocky hills. It blooms from June to September and seeds from July to October. The plant grows from two to three feet high and has a very distinct aromatic odor. The flowers vary from purplish to yellowish pink, white, and dotted, and are clustered in a solitary head at the end of the branch. Wild bergamot propagates by seed and by division of its roots. The brownish green seeds are seldom found in commercial seed samples.

Eradication.—Wild bergamot is not troublesome in cultivated crops or tilled land. Eradicate by digging out the plants or plowing the land.

Common Plantain (*Plantago major* L.)

Other common names.—Greater plantain, dooryard plantain, birdseed plantain, wayside plantain, broad-leaved plantain, and round-leaf plantain.

Description.—Common plantain is a perennial plant found commonly on lawns, along roadsides, and in waste places. It flowers from May to September and seeds from July to October. The leaves are very broad and quite leathery. The small, white flowers appear in long cylindrical spikes. Plantain reproduces itself by means of seeds which often appear in commercial seed of red clover, timothy, alsike clover, and white clover, and sometimes in redtop and bluegrass.

Eradication.—Meadows infested with plantain should be plowed and thoroly cleaned. A hoed crop or bare fallow gives excellent results. In reseeding the land use only well-cleaned and certified seed.

Lawns that are badly infested should be spaded up, cultivated, heavily manured, and reseeded thickly to pure Kentucky bluegrass and white clover or to any good lawn-grass mixture. Top-dress the lawn

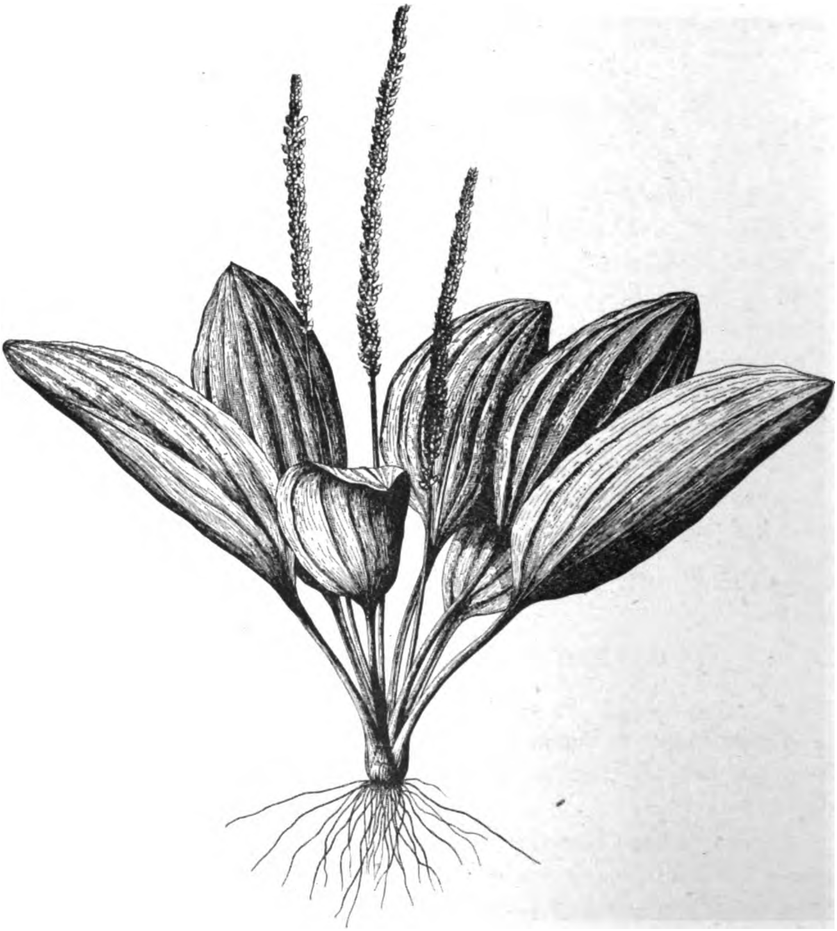

Fig. 19. Common Plantain

frequently and encourage a thick growth of grass. Remove stray plants from the lawn by pulling after a rain or by running a sharp knife deeply under the crown and pulling. Keep the lawn mowed closely and allow no plants to go to seed.

Bracted Plantain (*Plantago aristata* Michx.)

Other common names.—Western buckhorn, bristly buckhorn, and western ripple grass.

Description.—Bracted plantain is an annual or winter annual, and as yet is not very widely distributed throughout the state. The plant is generally found in grass lands, yards, waste places, and on dry prairies, and grows from six to twelve inches high. The leaves are more grass-like than those of the common plantain and on the cylindrical spikes are many sharp-pointed bracts from which it gets its name, bracted plantain. It flowers from May to September and seeds from June to October. The only method of propagation is by seeds which are found in commercial samples of alfalfa and redtop, and to some extent in red clover and timothy.

Eradication.—Sow only grass seed that is free from the seeds of weeds. Prevent plants from going to seed by pulling or removing with a knife. Keep the grass lands fully occupied with grass crops and the lawns richly fertilized.

Gumweed (*Grindelia squarrosa* (Pursh) Dunal.)

Other common names.—Rosin weed, scaly grindelia, gum plant, and tar weed.

Description.—Gumweed is generally a perennial altho it is sometimes a biennial. It is one of the composite group, flowering from June to September and seeding late in the fall. Gumweed is generally found in grain fields, waste places, along roadsides, and in clover and alfalfa fields. It grows from three to four and a half feet high, and is propagated only by seeds, which are blown about easily by the wind. The large terminal flowers are about an inch in diameter and bright yellow in color. The heads are very sticky. The whitish seeds are commonly found in commercial samples of alfalfa and sweet clover, and sometimes in redtop and alsike clover.

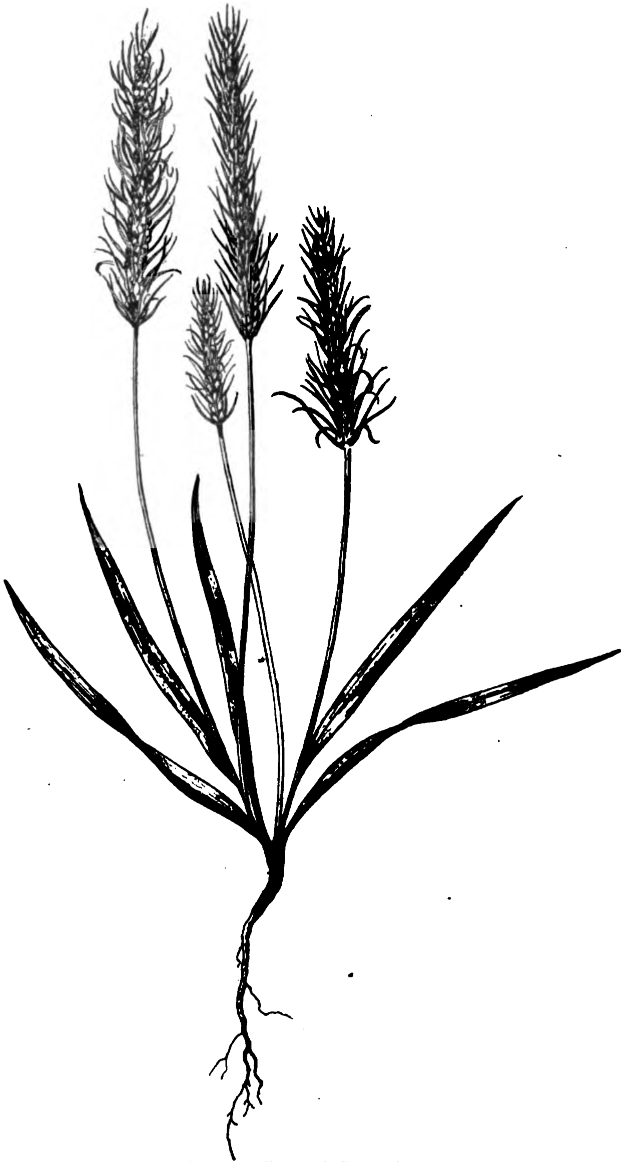

Fig. 20. **Bracted Plantain**

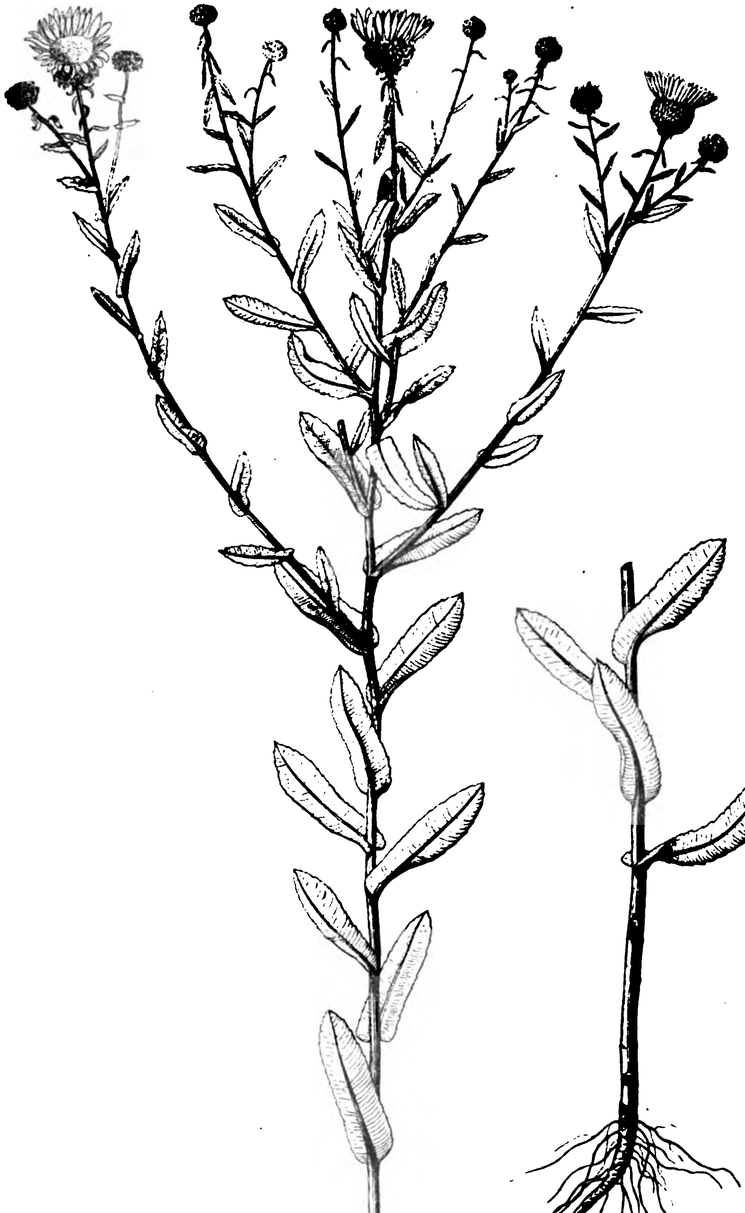

Fig. 21. Gumweed

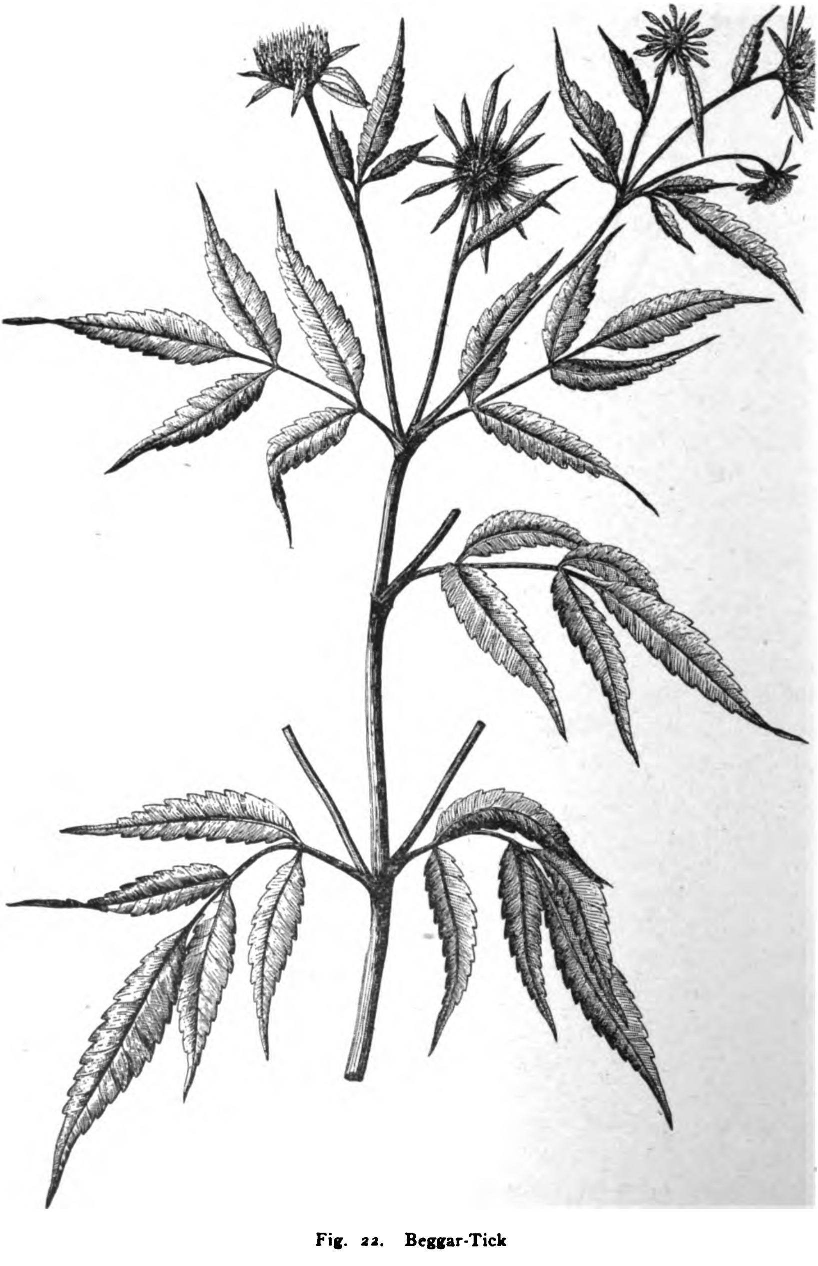

Fig. 22. Beggar-Tick

Eradication.—Good plowing and clean tillage will hold gumweed in check in tillable land. Sow only pure grass seed and well-cleaned grain. Pull or dig out all plants found growing in the fields or by the roadside before they go to seed.

Beggar-Tick (*Bidens frondosa* L.)

Other common names.—Sticktight, small bur-marigold, devils bootjack, pitchfork weed, and beggar-lice.

Description.—Beggar-tick is an annual plant, flowering from July to September and seeding from August to October. It grows most commonly in moist soil, in gardens, fields, along roadsides, and in waste places. The plant grows from two to five feet high. It is propagated by seed only. The yellow flower heads are about half an inch in diameter and are not very conspicuous. The wedge-shaped brown seeds are much flattened and generally have two awns. These awns are barbed and by clinging to the fur of animals and the clothing of men aid greatly in distributing the seed. They are seldom found in commercial seed.

Eradication.—Beggar-tick may be eradicated by preventing all plants from going to seed. Planting cultivated crops, with hand hoeing and pulling stray plants wherever found will keep it in check. Sow no grain or grass seed containing seeds of beggar-tick.

Roadside Thistle (*Cirsium discolor* (Muhl.) Spreng.)

Other common names.—Field thistle and plumed thistle.

Description.—The roadside thistle is one of the perennial thistles, altho it is sometimes a biennial. It is not considered so bad a weed as some of the other thistles. It flowers from July to November, and seeds late in the fall. It is generally found in fields, along roadsides, and in meadows and pastures. The leaves are deeply cut and are covered with spines and hairs. This thistle is not so prickly as most of the thistles. It grows from two to seven feet high and spreads by means of seeds, which are easily carried by the wind. The purplish flower-heads are from one and a half to two inches in diameter, and are generally solitary at the end of the branches. The seeds of roadside thistle are sometimes found in commercial samples of timothy, red clover, and alfalfa.

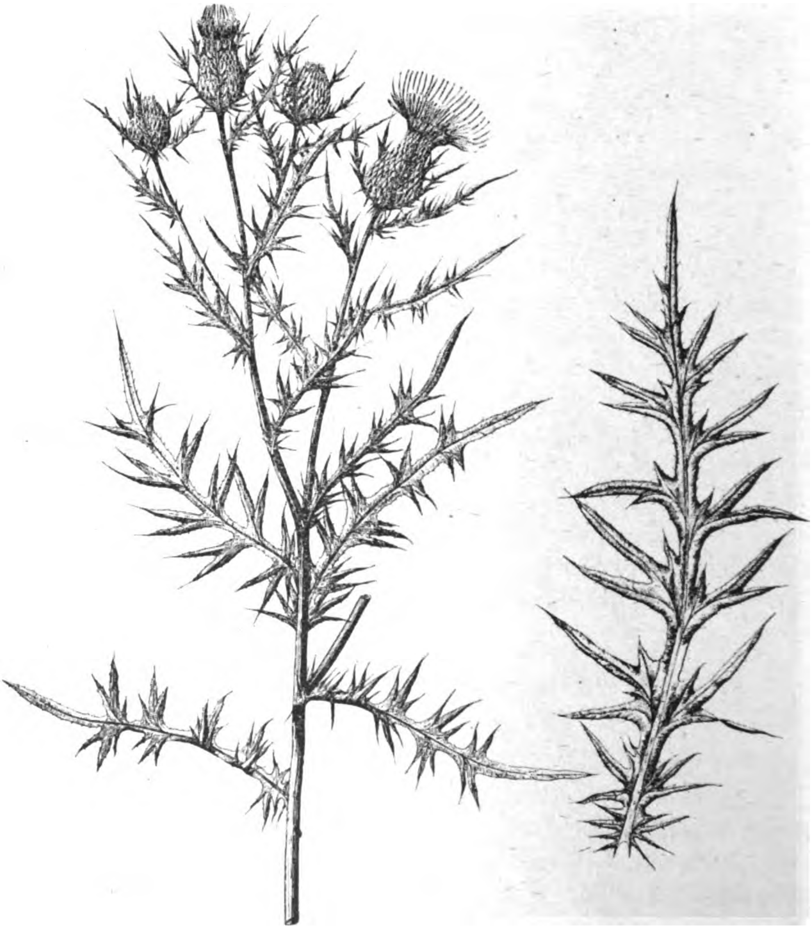

Fig. 23. Roadside Thistle

Eradication.—Spud out, pull, or otherwise destroy all thistles before seeds mature. Plow and cultivate fields that are badly infested and follow by a cultivated crop. Hoe by hand if necessary. Sow no seed containing seed of this plant.

Black-eyed Susan (*Rudbeckia hirta* L.)

Other common names.—Brown-eyed Susan, hairy cone-flower, yellow or ox-eye daisy, niggerhead, orange daisy, English bull's eye, and brown daisy.

Description.—Black-eyed Susan is a biennial, flowering from June to October and seeding from July to November. It generally grows on prairies, meadows, pastures, and in waste places, and is from one to three feet high. The flower heads are from two to four inches in diameter, and are solitary on long hairy stems. The center of the flower is dark purplish brown, and the ray flowers are orange-yellow. The plant is propagated by seeds which are often found in commercial samples of timothy, red clover, and alsike clover.

Eradication.—Black-eyed Susan is not a troublesome weed and yields to cultivation. Mowing each year before the seeds ripen will prevent reseeding.

Dandelion (*Taraxacum officinale* Weber.)

Other common names.—Blow-ball, lion's tooth, peasant's clock, doon-head clock, yellow gowan, priest's crown, Irish daisy, monk's head.

Description.—The dandelion is a perennial weed very commonly found on lawns and in waste places. It flowers from very early spring until freezing time, generally seeding about two weeks after flowering. It is one of the worst weeds found on the lawn. The leaves are spread on the ground in a flat rosette, making them hard to cut with the lawn mower. The young plants are excellent for greens in the spring, and the plant is also used medicinally. It has large yellow heads which open in fair weather and close on dark days. The light brown seeds are easily distributed by the wind, and are often found in lawn-grass mixtures, Kentucky bluegrass, and timothy seed.

Eradication.—The full occupation of the land with desirable grasses and crops will hold the dandelion in check in meadows and fields. It is most troublesome on lawns, since it seeds freely and the seeds blow

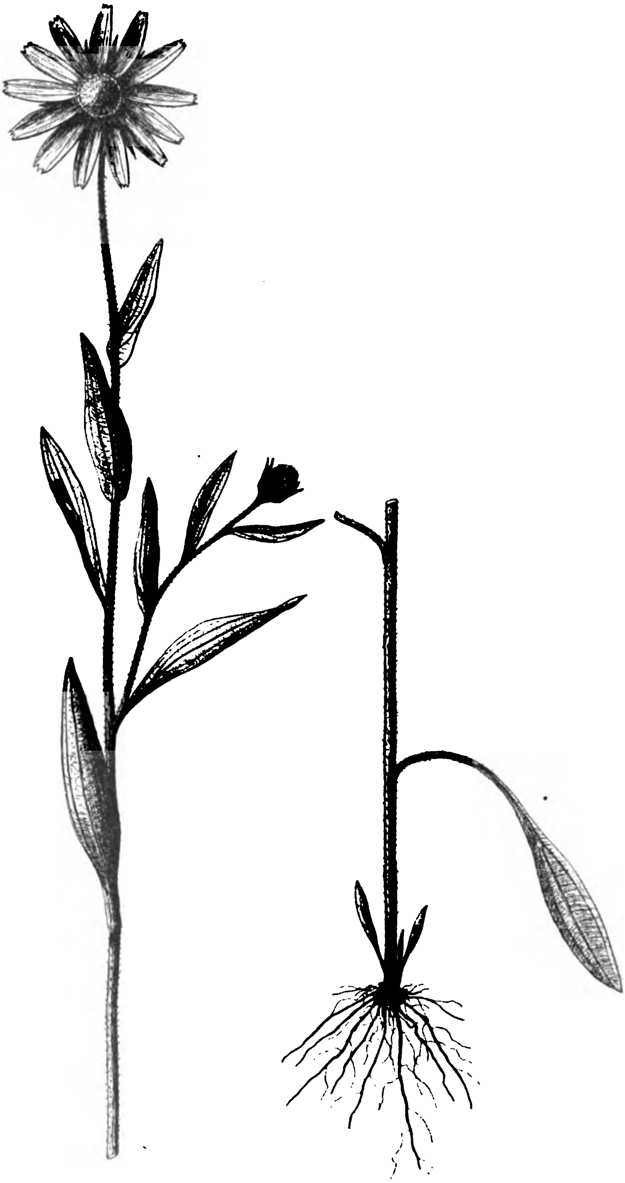

Fig. 24. Black-eyed Susan

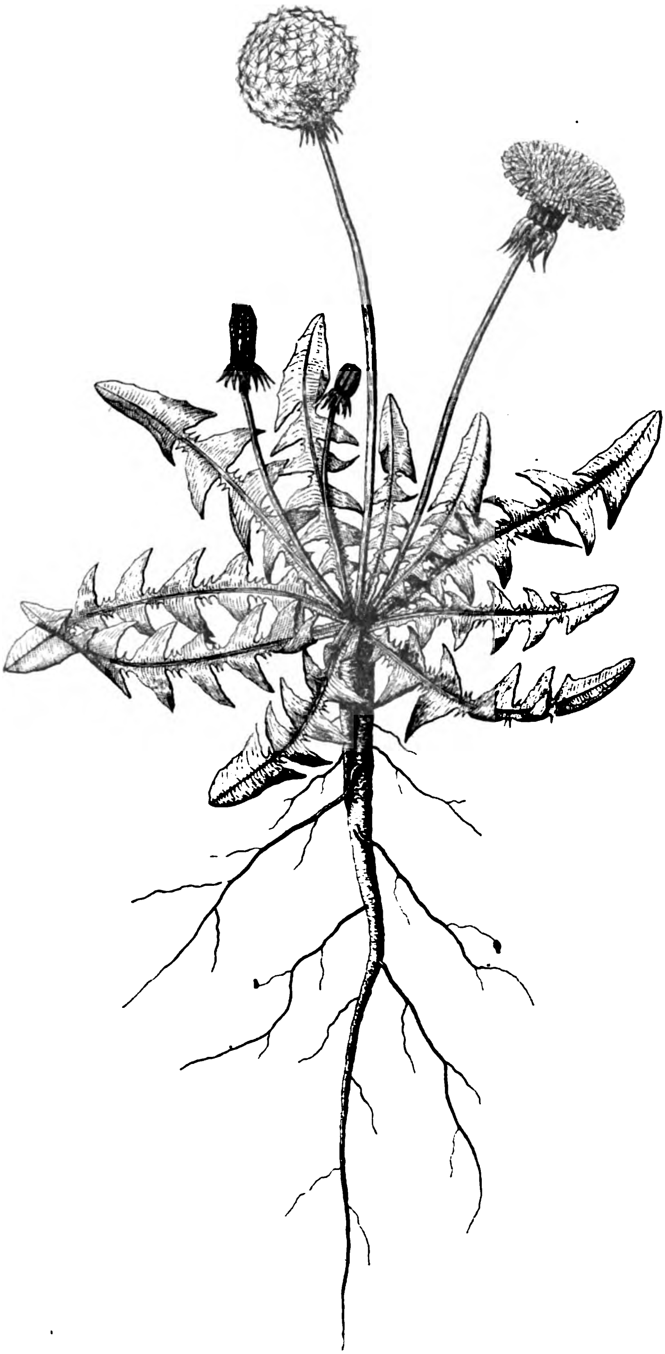

Fig. 25. Dandelion

about readily, thus reinfesting lawns that have been cleaned. The surest remedy against dandelions in the lawn is a rich soil frequently top-dressed with well-rotted manure or a nitrate of soda fertilizer. Such a soil thickly seeded to a mixture of Kentucky bluegrass, redtop and white clover will grow a thick turf that will be troubled but little by dandelions.

If a lawn is only thinly infested, spudding or digging out with a knife is often resorted to. Where badly infested, persistent spraying with sulphate of iron will hold them in check, altho it seldom results in complete eradication because the dandelion has become so universally established as to be quickly reseeded.

In spraying with iron sulphate it is best to make the application two or three days after the lawn has been cut. Spray on bright sunny days just after rather than just before a rain. A heavy rain will wash off the sulphate before the leaves are affected. Spraying at intervals of three or four weeks through an entire season is necessary to kill all of the dandelions. The solution for spraying should be composed of 1½ pounds of iron sulphate to 1 gallon of water. A compressed-air pump with a nozzle that will throw a fine spray is best. It should be tight enough not to leak. The solution will discolor clothing and cement work, so care must be used in applying it.

Summary of Information for Use in the Recognition of the Weeds Described in This Bulletin

Name	Class	Color of		Found in
		Flower	Seed	
1. Western wheat grass	Perennial	Green	Straw color	Red clover, bromus, alfalfa
2. Nodding wild rye	Perennial	Green	Straw color	Bromus
3. Hemp	Annual	Green	Gray-brown	Rarely occurs
4. Common smartweed	Annual	Green and pink	Brown	Timothy, flax, and red clover
5. Swamp dock	Perennial	Green	Light brown	Rarely occurs
6. Maple-leaved goosefoot	Annual	Green	Dark gray	Red clover and timothy
7. Ball mustard	Annual or biennial	Yellow	Straw color	All cereals
8. Indian mustard	Annual or biennial	Yellow	Reddish brown	All cereals and most forage crops
9. Tumbling mustard	Annual or winter annual	Light yellow	Light yellow to green	Timothy, alsike, and redtop
10. Canada milk vetch	Perennial	Greenish yellow	Deep yellow	Timothy
11. Indian mallow	Annual	Deep yellow	Grayish brown	Rarely occurs
12. Water hemlock	Perennial	White	Straw color	Timothy
13. Common milkweed	Perennial	Pink	Brown	Never found in crop seeds
14. Hoary vervain	Perennial	Purple	Brown	Timothy and red clover
15. Wood sage	Perennial	Light purple	Brown	Timothy, red clover, and cereals
16. Dragonhead mint	Annual or biennial	White and pink	Gray-brown	Timothy, red clover, occasionally in cereals
17. Wild bergamot	Perennial	Purple	Brown	Rarely occurs
18. Common plantain	Perennial	Pale green	Brown	Timothy, alsike, red clover, redtop
19. Bracted plantain	Annual or winter annual	Pale green	Light brown	Alfalfa
20. Gumweed	Biennial or perennial	Bright yellow	Cream color	Alfalfa
21. Beggar-tick	Annual	Yellow	Dark brown	Rarely occurs
22. Roadside thistle	Perennial	Purple	Tan with yellow tip	Timothy, red clover, cereals
23. Black-eyed Susan	Biennial	Deep yellow, dark center	Black	Lawn grass, timothy, and alsike
24. Dandelion	Perennial	Yellow	Light brown	Lawn grass

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The University of Minnesota

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BUTTERFAT LOSSES IN CREAMERIES

BY
R. M. WASHBURN AND A. C. DAHLBERG
DIVISION OF DAIRY HUSBANDRY
AND
JAMES SORENSON AND M. P. MORTENSEN
MINNESOTA STATE CREAMERY

UNIVERSITY FARM, ST. PAUL

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BUTTERFAT LOSSES IN CREAMERIES

By R. M. WASHBURN and A. C. DAHLBERG
JAMES SORENSON and M. P. MORTENSEN

The objects of this investigational work were: (a) to determine the butterfat losses occurring in the average well-conducted coöperative whole-milk and hand-separator creameries of this state and (b) to furnish additional information as to the accuracy of the Babcock test in commercial practice.

The degree of accuracy in testing and the butterfat losses often vary the percentage of overrun and the profits of a creamery to such an extent that they determine the success or failure of the plant.

It is generally agreed by dairy scientists that the Babcock method of determining butterfat in milk and cream yields results which compare favorably with the gravimetric analysis. Many butter-makers, however, are still a little skeptical regarding the accuracy of the test for they have experienced much trouble in trying to account for all the butterfat believed to have been received at the creamery. This is especially true of whole-milk creameries, where the actual overrun is often 5 or 6 per cent lower than the overrun calculated from the composition of the butter. Some have become thoroly convinced that in testing milk they should not read the 0.2 per cent of air in the upper meniscus as butterfat. On the other hand, in many plants receiving cream only, the fat paid for at the intake is apparently all recovered in the butter. The fat loss or the accuracy of testing or both varies considerably in different plants.

The work covered in this bulletin was done at the Minnesota state creamery at Albert Lea. The milk was delivered by the patrons daily and the cream was delivered sweet four or six times a week. The results reported were obtained during the normal operation of the creamery, no special effort having been made to reduce the amount of mechanical losses.

NORMAL VARIATIONS IN RESULTS OBTAINED BY THE BABCOCK TEST

Special care was taken in the operation of the Babcock test to insure accuracy. All the milk bottles were 18-gram 10 per cent bottles and all were carefully calibrated. It was apparent, however, that the length of graduations varied considerably, and a similar variation would be expected in the size of the meniscus. The menisci on 41 bottles were determined by reading with and without "red reader." They varied from 0.1 to 0.25 per cent and averaged 0.18 per cent. Several bottles having extremely wide necks were discarded. To avoid the error due to variations in size of the menisci, all milk tests were read with "red reader" and the results were increased by the customary 0.2 per cent meniscus. Repeated tests of the same sample (usually four tests of the same milk were made) never varied more than 0.1 per cent between the highest and the lowest, in fact, variations of more than 0.05 per cent were uncommon.

The testing of cream is more inducive to errors. A very sensitive four-bottle torsion cream balance and 9-gram, 6-inch, 40 per cent cream bottles were used in this work. The tests summarized in Table I were made on sweet cream containing from 25 to 35 per cent butterfat.

TABLE I
VARIATIONS IN CREAM TESTING

	Tests made on same sample	Tests agreeing within 0.25 per cent of average	Variation between highest and lowest
			Per cent
Sample showing greatest variation.....	10	8	0.75
Sample showing least variation........	5	5	0.00
Average of 204 tests	8.5	199*	0.45

* 97.5 per cent.

Altho the cream tests did occasionally vary 0.75 per cent on the same sample, the most common variation was 0.5 per cent. No variation of more than 0.5 per cent from the true test was obtained and 97.5 per cent checked within 0.25 per cent. Had this cream been richer or partly sour, much greater variations would doubtless have occurred, owing to the difficulty of obtaining a correct sample.

IMPORTANCE OF ACCURATE SAMPLING

The importance of accurate sampling was well demonstrated by the following experiment. Two one-pint samples were very carefully taken from each of ten different cans of sweet cream. One sample from each can was sent to a chemist who resampled it and made duplicate analyses for fat. The same samples were then given to another chemist who also made duplicate determinations for fat. The samples of the second set were tested by the Babcock method, each sample being tested eight times and the average taken as the true test. Table II gives the tests showing the greatest and least variations between the chemical and Babcock methods and the average of all tests.

TABLE II

VARIATIONS BETWEEN CHEMICAL AND BABCOCK TESTS

	Test by first chemist	Test by second chemist	Average by chemists	Average by Babcock test	Variation between chemists	Variation between chemical and Babcock tests
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Sample showing greatest variation between chemical and Babcock tests	32.40	29.66	31.03	29.87	2.74	1.16
Sample showing least variation between chemical and Babcock tests	29.31	28.84	29.08	29.06	0.47	0.02
Average of ten samples.	29.57	29.03	29.30	29.32	0.97	0.39

It will be noticed that there was two and one half times as much variation between the two chemical analyses as there was between the average gravimetric analysis and the Babcock tests, and that the two chemists had greater variations in results than is ever countenanced with the Babcock method. In view of the acknowledged greater accuracy of the chemical analysis and the close agreement between the duplicates analyzed by the same chemist, *it is apparent that the errors in sampling were far more important in influencing the accuracy of results than were the errors due to the methods used in testing.*

DRIP METHOD OF SAMPLING MILK

It is the practice of whole-milk creameries to take a composite sample of the milk sent in by each patron and to test the samples weekly or semi-monthly. By the drip method of sampling the daily overrun may be figured. The samples used in this test were caught by means of a pet-cock placed in the sanitary piping leading from the milk heater to the separator. The sample was representative of all the milk received, because (1) the milk had just been warmed and mixed in the milk heater and (2) the flow of milk to the separator was steady. From 2 to 4 quarts were caught from every 1,000 pounds of milk handled. Four tests were made of every drip sample to avoid, as far as possible, all errors in testing.

During a period of 43 days the milk sent in by each patron was tested daily and the fat was calculated for each portion. The sum of the fat obtained by the individual tests was assumed to be correct and the fat obtained by the test of the drip sample was compared with it. Table III shows the percentage of error in the total fat received in the milk when determined by the drip sample.

TABLE III

Accuracy of the Drip Sample

55.8 per cent of tests made contained an error of 0-1.0 per cent
27.9 per cent of tests made contained an error of 1-2.0 per cent
11.6 per cent of tests made contained an error of 2.01-3.0 per cent
4.1 per cent of tests made contained an error of 3.01-6.9 per cent
Average of 43 samples.......................... 0.39 per cent

It is apparent that the drip sample can not be relied upon absolutely but that it does give a very good approximation of the true overrun for each day, and that the average overrun covering a considerable period of time will be essentially correct.

COMPARISON OF FAT IN MILK WITH THAT IN THE CREAM OBTAINED FROM IT

The amount of fat in the milk was determined by daily tests of samples of the milk furnished by individual patrons. The cream from the separator was caught in 5-gallon cans and each can was weighed and tested separately. The weight of skimmilk was assumed to be the difference between the weights of the milk and the cream. A drip sample of skimmilk for testing was obtained by means of a petcock placed in the pipe leading from the pump to the skimmilk tank. In testing skimmilk, 20 cubic centimeters of acid were used, the 18-inch tester was whirled at the rate of 900 revolutions per minute for 10 minutes. The skimmilk was tested in duplicate and the samples were later tested by the gravimetric analysis. Table IV gives the comparison between the amount and the percentage of fat in the milk and that recovered in the cream and skimmilk.

TABLE IV

Comparison of Butterfat in Milk and That in the Cream Separated From It

	Pounds tested	Average test	Pounds fat	Percentage error
Milk	204,750	3.845	7,872.6	
Cream	19,976	38.77	7,745.6	
Skimmilk, Babcock test	184,774	0.018	33.2	
Skimmilk, gravimetric test	184,774	0.07	129.3	
Total for cream and skimmilk, Babcock test	204,750	3.799	7,778.8	−1.22
Total for cream and skimmilk, gravimetric test	204,750	3.846	7,874.9	+0.03

The amount of fat in the skimmilk and in the cream according to the Babcock test, did not equal the amount of fat in the milk, but lacked 1.22 pounds for every 100 pounds of fat separated. If the cream and skimmilk had been mixed together again and the percentage of fat in the resulting milk calculated from the skimmilk and cream tests, the milk would have tested 0.045 per cent too low. If, however, the gravimetric test of the skimmilk is used, the fat checks exceedingly close. So small a difference as 0.03 pound on every 100 pounds of fat separated or 0.001 per cent on the average milk tests is an exceedingly close agreement and helps to prove that the Babcock test gives results on skimmilk which are too low. *Those butter-makers who consider that the milk test gives too high results fail to recognize the acknowledged low results on skimmilk given by the Babcock test.*

COMPARISON OF FAT IN CREAM WITH THAT IN BUTTER

It logically follows that the amount of fat in the cream should be checked against the amount of fat recovered in the butter. The amount of fat in the cream was determined as previously explained. Samples of the butter were taken from at least 10 different places in the churn and given a chemical analysis. The fat remaining in the cream vat was washed out with hot water which was then weighed and sampled. The butter wash-water was weighed into the churn and sampled as it drained out through the doors. The hot churn wash-water was weighed into the churn and quickly sampled as soon as the churn was stopped. Wash-waters were all tested by the Babcock method, which was assumed to give the correct test. The buttermilk was tested by the Babcock and the gravimetric methods. Table V shows the accuracy with which the fat in the cream as determined by the Babcock method was accounted for in the butter. The itemized losses are not given, as they are included in later tables.

TABLE V

COMPARISON OF AMOUNT OF BUTTERFAT IN CREAM AND AMOUNT OF BUTTER CHURNED FROM IT

	Total fat	Losses	Net fat	Percentage error
	Pounds	Pounds	Pounds	
Butter by gravimetric test	3,914.6	....	3,914.6	....
Cream by Babcock test, Babcock test on buttermilk	3,976.9	31.1	3,945.8	+0.79
Cream by Babcock test, gravimetric test on buttermilk	3,976.9	56.6	3,920.3	+0.14

It is apparent that when the fat losses are subtracted from the fat in the cream, the difference is still greater than the fat in the butter, because the Babcock method gives results on buttermilk which are too low. When the gravimetric test of buttermilk was used, the figures showed close agreement between the amount of fat in the cream and that recovered in the butter.

FAT LOSSES IN A CAREFULLY OPERATED CREAMERY

In considering the tables showing the fat losses during the manufacture of the product, it must be borne in mind that the vats, pipes, pump, and other apparatus were first well rinsed with water in the usual manner to remove the fat adhering to them and that this rinse-water was added to the cream. The weigh can, vats, flash pasteurizer, pipes, etc., were then thoroly scrubbed with hot water, the water was then weighed, stirred vigorously, and quickly sampled. The Babcock test (using skimmilk bottles) on the wash-waters was assumed to give accurate results. Skimmilk and buttermilk were also tested by gravimetric analysis. To obtain the fat loss at any point the work was repeated not less than five nor more than forty-three times, the number of repetitions depending upon the magnitude of the factor and the normal variations occurring from day to day. The first column of Table VI gives the average test as determined by the Babcock method; the second column includes the gravimetric analysis of the skimmilk and buttermilk; and the third column gives the average daily loss of fat, in pounds, in those places where the volume of material handled has little effect on the amount of fat lost.

To show the loss at each point of manufacture, the butterfat losses are shown, the losses are then totaled for a hand-separator creamery and a whole-milk creamery, and this total loss added to the butterfat recovered in the butter should equal the total fat received at the intake of the creamery. The difference between the sum of the total fat accounted for in the butter plus the fat losses and 100, gives the percentage of the total fat received at the intake which was not accounted for in the manufacture of the butter.

TABLE VI

BUTTERFAT LOSSES IN A CREAMERY

	Fat loss as determined by		
	Babcock test	Gravimetric test	Fat loss
	Per cent	Per cent	Pounds
Whole milk received	100.0	100.0	....
Fat losses in skimmilk	0.49	1.64	....
Milk weigh can, vat, heater	0.13	0.13	0.38
Cream forewarmer, flash pasteurizer, and cooler	0.23	0.23	1.25
Cream ripener	0.07	0.07	0.15
Buttermilk	0.29	0.9	....
Butter wash-water	0.03	0.03	0.14
Churn wash-water	0.14	0.14	0.61
Total fat losses for hand-separator creamery	0.76	1.4	....
Total fat losses for whole-milk creamery	1.38	3.17	....
Fat recovered in butter	96.72	96.72	....
Fat accounted for	98.1	99.89	....
Fat not accounted for	1.9	0.11	....

The accuracy of the figures is evident because they account for 99.89 per cent of all the fat received as given under the column headed "gravimetric test." The fat lost mechanically is very slight at any one point in the process, but in the aggregate amounts to 2.53 pounds or 0.6 per cent of the total amount of fat received. This includes the fat remaining in the weigh can, milk receiving vat, milk heater, cream forewarmer, flash pasteurizer, cooler, cream ripener, butter wash-water, and churn wash-water. Careless work would, of course, greatly increase this loss. In large creameries the percentage of mechanical losses would be greatly decreased because this loss is almost independent of the volume of product handled.

The chief losses of fat are sustained in the skimmilk and buttermilk. The losses from these sources are usually underestimated, because the Babcock test gives results which are approximately three times too low. When the Babcock test is used, about 2 per cent of the fat received at the intake is still unaccounted for, and most of this fat has been actually lost in the skimmilk and buttermilk. The fat lost in the skimmilk was 1.64 per cent of the total and that lost in the buttermilk was 0.93 per cent. The size of the creamery will not affect the percentage of these fat losses.

The effect of the various fat losses is better understood by the average creameryman when expressed on the basis of overrun. If we assume that the finished butter will contain 80 or 82 per cent fat, the following overruns are the largest that can be obtained:

	Per cent	Per cent
Overruns	80.0	82.0
Calculated without any fat losses	21.95	25.0
Hand-separator creamery (1.4 per cent fat losses)	20.24	23.25
Whole-milk creamery (3.17 per cent fat losses)	18.07	21.04

A hand-separator creamery loses about 1.7 per cent of its overrun, owing to the fat losses; and a whole-milk creamery loses about 3.9 per cent, altho the amount of these losses will vary according to the skill of the operator and the size of the plant. The percentages given in the tables are representative of the well-operated plants of this state.

EXPERIMENTS WITH THE BABCOCK TEST

EFFECT OF TIME WHEN WATER IS ADDED

Not infrequently the operator of a creamery will modify the details of the operation of the Babcock test, especially in regard to the time of adding the water. To throw light on this question, the same sample of milk was tested in four ways as follows: Method I was that usually recommended as standard, namely, the sample was first centrifuged, or whirled in the centrifugal machine, for four minutes, then water was added to fill the bottle to the bottom of the neck. This was centrifuged two minutes, water again added to raise the fat this time sufficiently high in the neck to enable reading, and then whirled three minutes, all at full, strong speed, namely, about 800 revolutions per minute for an 18-inch wheel. In method II the bottles were filled to the top after the first centrifuging. In method III the bottles were filled to the neck before centrifuging, and then filled to the top after the first centrifuging. In method IV the bottles were filled to the top before the first centrifuging. In comparing these methods the same sample of cream was tested 16 times, 4 times by each method. Table VII shows the average of two samples of cream:

TABLE VII
COMPARISON OF METHODS OF TESTING CREAM

	Method I	Method II	Method III	Method IV
	Per cent	Per cent	Per cent	Per cent
Sample I	32.12	32.12	32.19	32.12
Sample II	33.75	33.83	34.42	34.17

All methods gave fairly accurate results. Method II proved about equal to method I when centrifuged strongly, but methods III and IV are more inducive to error and are more difficult to operate conclusively. If method I is employed there is much less danger of error and a clearer fat column will usually be obtained.

The same methods were tried on milk with the following results:

TABLE VIII
COMPARISON OF METHODS OF TESTING MILK

	Method I	Method II	Method III	Method IV
	Per cent	Per cent	Per cent	Per cent
Sample I	2.53	2.51	2.54	2.45
Sample II	4.01	3.99	4.01	3.92

Method IV uniformly gave lower tests, and as noted under cream testing, methods II, III, and IV required much more skill on the part of the operator to obtain satisfactory results.

EFFECT OF SPEED OF TESTER AND TIME WHIRLED

The standard Babcock method, No. I, was compared with centrifuging for a longer period of time at less speed. An 18-inch tester was used. The average of four tests by each method resulted as follows:

800 revolutions, standard time	32.37 per cent
500 revolutions, standard time	31.44 per cent
500 revolutions, 19 min. total	31.66 per cent

Slow speed resulted in a lowering of the test, which was not raised to normal even tho the time of centrifuging was doubled.

COMPARISON OF MILK AND CREAM BOTTLES FOR CREAM TESTING

It is rather interesting to note that cream does not test the same in milk test bottles as in cream test bottles. Testing cream in milk test bottles was accomplished by dividing the 9-gram cream sample among several bottles, usually three, adding enough water to each bottle to total 9 grams, and completing the test by the usual method of testing cream. It was found that the number of milk bottles used in making each test did not affect the readings, two bottles gave the same result as four or seven bottles. In all, fifteen cream samples were tested 8 times each in cream bottles and 8 times in milk bottles, using three bottles for each test. Hence the experiment included 120 cream tests and 360 milk tests.

The percentage of fat indicated to be present in the cream bottles exceeded that in the milk bottles by an average of 0.37 per cent, the least difference being 0.21 per cent and the greatest 0.86 per cent. The amount of residual fat in the test bottle possibly could account for this difference, owing to the fact that a small amount of fat is more easily washed and therefore more of the impurities are centrifuged out.

SUMMARY

1. The skimmilk retained 1.64 per cent of the total fat received at the factory and the buttermilk 0.93 per cent.

2. About one half of one per cent of the total fat received was lost mechanically in vats, pipes, etc.

3. The creamery receiving cream lost about 1.4 per cent of the total butterfat received, during the process of manufacture and saved about 98.6 per cent.

4. The creamery receiving milk lost about 3.17 per cent of the butterfat during the process of manufacture and saved about 96.83 per cent.

5. When the losses were correctly considered the butterfat in the milk, determined by the standard Babcock methods, checked with the fat in the cream separated from it.

6. Likewise, the butterfat in the cream, as determined by the Babcock test, checked with the fat in the butter determined by chemical analysis.

CONCLUSIONS

1. The Babcock test, when carefully operated, gives results which are so nearly absolutely accurate that the error does not materially affect the overrun.

2. The drip method of sampling milk is fairly accurate.

3. The sampling of cream is very inducive to errors unless given special attention.

4. In the Babcock fat test of milk, the addition of water twice gave far more dependable results than did any of the several modifications of the method.

5. Long continued centrifuging at a low speed will not compensate for the higher speed and shorter time generally recommended. The higher speed gives the higher reading.

6. Cream tested in milk bottles gives readings uniformly too low.

7. Skimmilk and buttermilk tested by the Babcock method indicate only about one third to one half as much fat present as is shown by chemical analysis.

8. The fat column in the test of milk should be read from the extreme bottom to the extreme top, meniscus included.

9. If the fat standard for butter be fixed at 80 per cent, the overruns, within the limit of safety, will be about 22 per cent for hand-separator creameries and about 19 per cent for whole-milk creameries.

10. With the same chemical composition of butter, the overrun will be very much reduced if weigh can, vats, pipes, and pumps are not thoroly rinsed or if the separator is not so balanced as to permit of full high speed or if the cream is churned too warm or too cold or too soon after cooling. Intelligent attention throughout the process is necessary to secure results as good as those shown in this study.

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The University of Minnesota

AGRICULTURAL EXPERIMENT STATION

FARM TENANCY AND LEASES

BY

A. H. BENTON

DIVISION OF AGRONOMY AND FARM MANAGEMENT

UNIVERSITY FARM, ST. PAUL

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SUMMARY

1. Farm tenancy has been rapidly increasing in Minnesota, particularly in the southwestern part of the state where the average land values are highest. (See Table I and Figures 1 and 2.)

2. The farm survey data (Tables III and V) indicate that both landlord and tenant receive higher returns where they operate under a share lease than under either a cash or mixed cash and share lease. This is due in a great measure to the larger amount of operating capital used on the share rented farms.

3. Nearly all leases are for short terms, usually three years or less. This is not conducive to good farming but neither landlords nor tenants want long-term leases on account of speculative land prices and lack of well-established relations between landlords and tenants. Long-term leases are a result rather than a cause of high-class tenant farming.

4. The forms of leases in most common use in Minnesota are the one-third crop share lease, the one-half crop share lease, the one-half crop and livestock share lease, and the cash lease.

5. No one lease is suitable for all conditions but forms are suggested with footnotes which make it possible to adapt them to specific cases.

6. The proper basis for drawing up a just and equitable lease is that the landlord and tenant each contribute to the expense in proportion to his share in the returns. Data in Tables VI to XIII inclusive, show the expense of producing wheat, oats, barley, hay, and corn, and of maintaining a dairy cow. A division of the expense between landlord and tenant is suggested.

FARM TENANCY AND LEASES

By A. H. Benton

INTRODUCTION

Until recent years land has been plentiful and cheap, and the question of ownership of farm land has not been a vital one in the minds of the people. In a pioneer country tenancy is not a problem, for there is land sufficient for all. As a country develops and grows more populous and land becomes scarce, those owning good land begin to rent to others. The public is now becoming vitally concerned over the amount of farm tenancy existing and over its tendency to increase. Within the last twenty years practically all land ready for cultivation has been put into crops and land values have advanced rapidly. This increase in land values has been attended by much speculation and a rapid increase in tenancy, particularly in the richer agricultural sections. At first this practice attracts no attention, but as it becomes more and more common the evils begin to appear. In all communities where tenancy has developed to any extent the effect seems to be bad. Soil fertility is being more rapidly depleted, farm and civic improvements are greatly retarded, and the social life of the community is not satisfactory. Tenancy is becoming a question of national importance and measures are being proposed to reduce it or at least to prevent further increase.

PURPOSE OF STUDY

It is the purpose of this study to consider the rental systems and leases now in use in Minnesota and to make suggestions as to how they may be made more satisfactory to both landlord and tenant and more conducive to better farming. No effort is made to go into the details of the evils of tenancy, to discuss its causes, or to suggest a remedy. That rented farms make up a considerable proportion of the total and that they are rapidly increasing in number is accepted as a fact established by census figures. While in time some satisfactory remedial measures may be worked out, an urgent and immediate need is for better rental systems, and this is the phase of the subject taken up in this investigation.

SOURCES OF INFORMATION

Figures on the amount of land tenancy and its rate of increase were obtained from United States census reports. Data on the income of landlords and tenants in various parts of the state were obtained from farm management surveys made in several different areas.

The discussion of rental systems and the suggested leases are largely based upon the experience of landlords and tenants and the leases used by them. The investigations were carried on through correspondence with county agents, agricultural high school instructors, and farmers in all sections of the state where farms are rented in any considerable number; and through personal interviews with a large number of farmers in these regions.

TENANCY IN THE UNITED STATES

The amount and increase of land tenancy in the United States are shown in Table I. It will be noted that there has been an increase in farm tenancy of 11.4 per cent from 1880 to 1910, or approximately 3 per cent each decade.[1] In 1910, 37 per cent of all farms in the United States were operated by tenants. If the rate of increase remains the same, approximately 50 per cent of the farms will be operated by tenants in 1950.

TABLE I
LAND TENANCY IN THE UNITED STATES

	1880	1890	1900	1910
	Per cent	Per cent	Per cent	Per cent
Owners and managers	74.4	71.6	64.7	63.0
Tenants	25.6	28.4	35.3	37.0

Tenancy develops most rapidly in the richer agricultural districts. These districts offer the greatest opportunity to absentee investors as the land is increasing most rapidly in value and crops are reasonably certain. The high prices make it difficult for farmers to buy, and some not interested in land speculation prefer to rent, since the rent charged is lower than the interest on the purchase price of the land. The richest two agricultural states of the Union, Iowa and Illinois, are also the two northern states with the largest proportion of tenant farms, the former having according to the last census 37.8 per cent and the latter 41.4 per cent.

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[1] U. S. Census for 1880, 1890, 1900, and 1910.

TENANCY IN MINNESOTA

Tenancy in Minnesota has been increasing about one half per cent each year for the last thirty years. In 1910, of the 21 per cent of farms operated by tenants, 14.2 per cent were share rented and 6.8 per cent cash rented. Table II shows the proportion of tenant farms in Minnesota and adjoining states. It will be noted that Iowa has the highest percentage of tenants. Southern Minnesota has the same agricultural possibilities as Iowa and in this section tenancy has developed most rapidly. According to the 1910 census, in 19 counties of Minnesota more than 30 per cent of the farms were operated by tenants, and these were in southern and southwestern Minnesota.

TABLE II
TENANT FARMS IN MINNESOTA AND ADJOINING STATES (1910 CENSUS)

	Owners and managers	All tenants	Cash tenants	Share tenants
	Per cent	Per cent	Per cent	Per cent
Minnesota	79.0	21.0	6.8	14.2
Wisconsin	86.1	13.9	7.2	6.7
Iowa	62.2	37.8	21.7	16.2
North Dakota	85.7	14.3	3.2	11.1
South Dakota	75.2	24.8	5.7	19.1

Figure 1 shows the distribution of tenant farming in Minnesota and Figure 2 the distribution of land values. There is a remarkable similarity between these two figures. In general, the counties having the highest proportion of tenant farms also have the highest land values. There are about a dozen counties in the east central part of the state in which land values are high but in which the number of tenant farms is considerably lower than in the neighboring counties. This is in some measure due to the proximity of a large center of population, the cities of St. Paul and Minneapolis, with attending high land values. Table II indicates that there are nearly four times as many share tenants as cash tenants in North and South Dakota. In Wisconsin the two classes of tenants are nearly equally divided, but in Iowa there are nearly one fourth more cash tenants than share tenants. In Minnesota there are more than twice as many share tenants as cash tenants. As farm tenancy becomes more prevalent and agricultural land becomes more valuable and a source of speculative investment, cash tenancy develops rather than share tenancy.

Share tenancy is a more generally profitable and satisfactory rental system than cash tenancy. This is the judgment of the most progressive farmers, and it is borne out by data available from different parts of Minnesota. A farm management survey in Rice County, in 1912, included sixty tenant farms.[2] These farms were divided into three groups consisting of (1) twenty-two cash rented farms, (2) nineteen share rented farms, and (3) nineteen mixed cash and share rented farms.

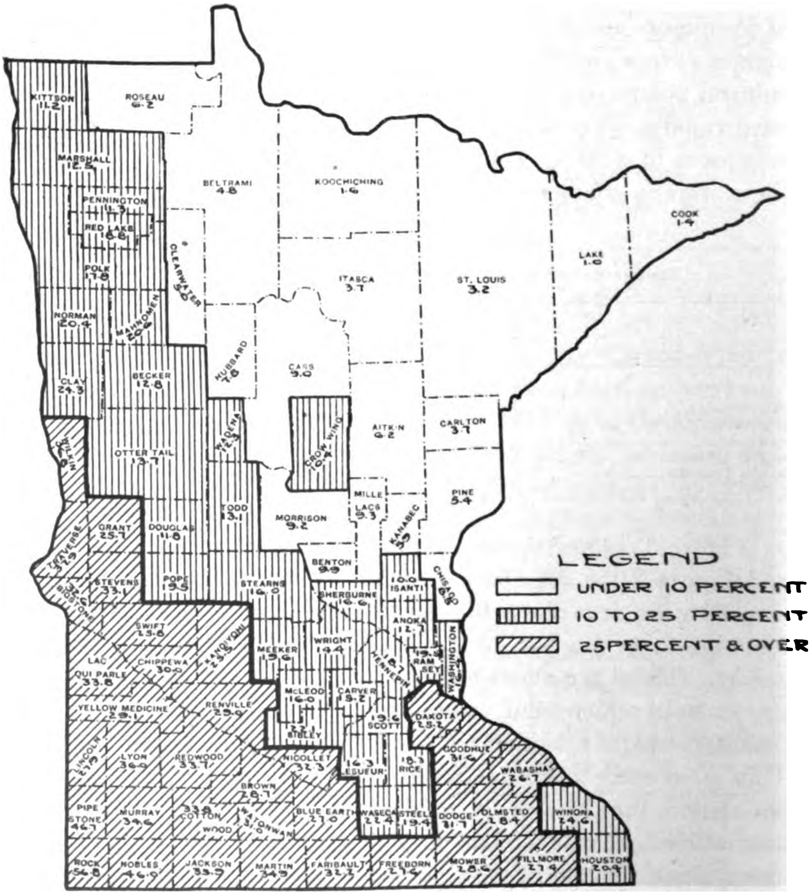

Fig. 1. Percentage of Tenant Farms, 1910 Census Average for State, 21 Per Cent

The share tenants owned a part of the productive livestock, and all of the horses and machinery. The returns from crops sold were divided equally but the division of the returns from livestock and livestock products sold depended on the proportion of the productive livestock owned by each. In the mixed group are the farmers who paid cash for a part of the land rented, as for example the hay and pasture land, and shared the small grain with the landlord.

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[2] The larger part of the data of this survey is reported in Minn. Agr. Exp. Sta. Bull. 172 by Andrew Boss, A. H. Benton, and W. L. Cavert, "A farm management study in southeastern Minnesota." 1917.

The farms operated under the crop and stock share system returned nearly three times as large a labor income as those operated under the cash rental system, and they also returned more than twice as large a percentage on the landlord's investment (Table III). Four factors can be named which appear to be the principal ones in giving the share renters the decided advantage over the other two groups. These factors are size of business, crop yields, returns per unit of productive livestock, and effective use of man and horse labor (Table IV). The share-rented farms excel in all these points.

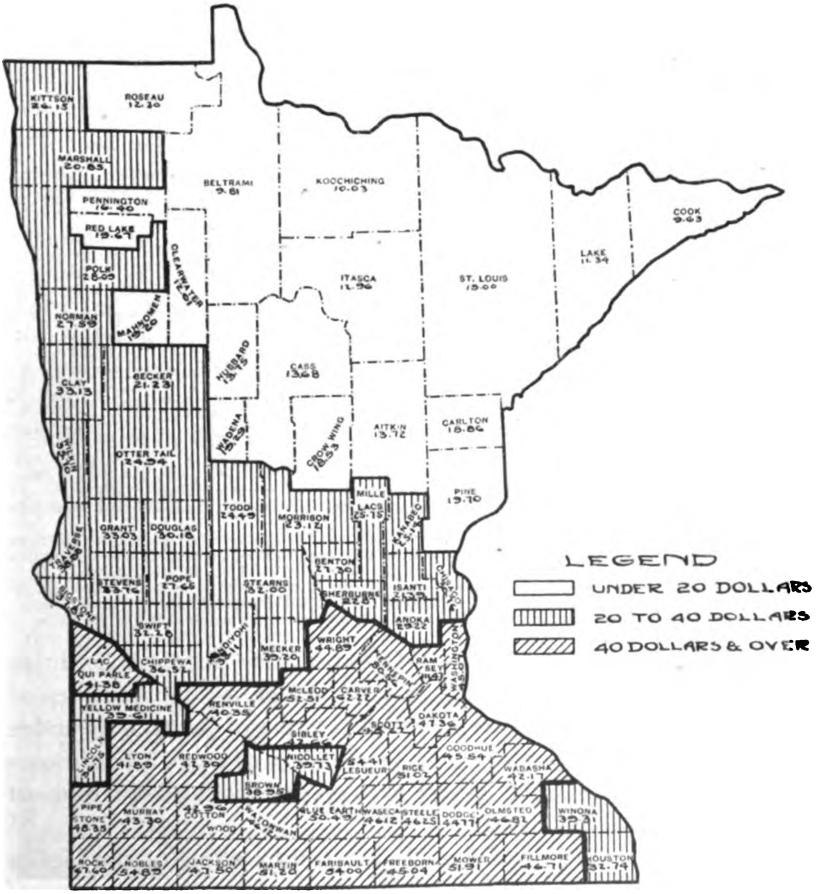

Fig. 2.-Average Value Per Acre of Farm Land, 1910 Census Average for State, $36.82

Attention should be called to the amount of capital owned by the average tenant of the different groups. The average share tenant had less capital of his own invested in livestock, machinery, and supplies than the cash tenant, but the share rental system gave him the benefit of nearly an equal amount of the landlord's capital, the result being that the average amount of operating capital on the share rented farms was $2,940 as compared to $1,937 on the cash rented farms.

TABLE III

RELATION OF RENTAL SYSTEM TO RETURNS RECEIVED BY LANDLORDS AND TENANTS
SIXTY RICE COUNTY TENANTS, 1912

	All rental classes	Cash rent	Mixed share and cash rent	Share rent
Number of tenants	60	22	19	19
Average labor income of tenants[*]	$323	$182	$279	$530
Percentage returned on landlord's investment[†]	3.85	2.3	3.3	5.0

[*] Labor income, or operator's labor income, is the balance left after deducting from farm receipts the three following items, (1) farm expenses, (2) interest on the average capital invested, and (3) value of unpaid family labor not including the operator's.

[†] Landlord's percentage on investment is the rate of interest that the landlord receives on his invested capital. It is calculated on the landlord's receipts after deducting taxes and other necessary expenses.

TABLE IV

RELATION OF CERTAIN EFFICIENCY FACTORS TO THREE TENURE GROUPS

	Share tenants (19)	Mixed cash and share tenants (19)	Cash tenants (22)
Total farm capital	$20,020	$13,633	$11,620
Tenant's capital	$1,708	$1,524	$1,937
Operating capital[*]	$2,940	$1,553	$1,937
Total acres	185	152	119
Crop acres	117	105	83
Animal index[†]	110	93	100
Crop index[‡]	98	93	90
Days of productive labor per man per year[§]	312	221	242
Days of productive labor per horse per year	104	95	76
Labor income	$530	$279	$182

[*] "Operating capital" is all the farm capital except that invested in land and buildings. It includes livestock, machinery, equipment, feeds, and supplies.

[†] "Animal index" is the percentage of the returns from productive livestock on one farm as compared to the average on a group of farms in the same neighborhood, including the one under consideration.

[‡] "Crop index" is the percentage of crop yields on one farm as compared to the average on a group of farms in the same neighborhood, including the one under consideration.

[§] "A day of productive labor" is the amount ordinarily accomplished in a day of 10 hours.

Similar records from 63 tenant farms in nine different localities in as many counties also indicate the advantage of the share-rental system. Table V shows the average labor income of the tenants under share, cash, and mixed cash and share rental systems. It also shows the percentage returned, above expenses, on the landlord's investment under each of the three systems.

A comparison of Tables III and V shows the effect of the higher price of farm products. The relative returns from the three rental methods are the same for both landlord and tenant except that the average labor income on the cash tenant farms is larger than on the mixed tenant farms (Table V). This is due to the higher prices of farm products in 1915 as compared with those of 1913, with little or no increase in the rate of cash rent.

TABLE V

RELATION OF RENTAL SYSTEM TO RETURNS RECEIVED BY LANDLORDS AND TENANTS
SIXTY-THREE TENANTS IN NINE COUNTIES IN 1915

	All rental classes	Cash rent	Mixed share and cash rent	Share rent
Number of tenants	63	16	26	21
Average labor income of tenants	$811	$732	$699	$1,010
Percentage returned on landlord's investment	3.3	2.5	3.1	4.1

Tenants as a class are by no means all poor and shiftless farmers, as is frequently intimated. Many of the most progressive and prosperous farmers were at one time tenants and were frequently hired farm laborers before they became tenants. It is true that they do not keep up the productive power of the soil. They must get all they can from a farm while they have it because usually they do not know whether they can remain on the farm for more than one year. This is particularly true in the more recently developed agricultural states where land speculation is rife and many landlords are holding their farms until a sale can be made at a profit.

In Minnesota as in most other states, the relationship between landlord and tenant has not been well established, and both parties hesitate to make a long-term lease. Justice and equality in leasing systems has not been well worked out, and with continually increasing land values and fluctuating prices it is very difficult to establish standards. Since it is becoming more and more difficult for renters to buy land because of increased prices, and since many landlords who have been speculating in land are now beginning to develop their holdings, there is an increasing demand for more light on the subject of land leases.

Those most familiar with agricultural land questions feel that the best agriculture and the most highly developed citizenship depend on the farmers owning the land that they operate. On the other hand, the fact that tenancy is present and that it is increasing must be recognized. Much can be done toward minimizing the ill effects of tenancy if good tenants can be induced to stay on the same land year after year. The longer operation of the same farm by one tenant will be greatly encouraged if more just and equitable leasing systems are used. With the increasing price of land, a more progressive, thrifty class of tenants appears. Such tenants recognize the ill effects of too frequent changes. On the other hand, landlords see the necessity of keeping good tenants. Most tenants as well as most landlords hesitate to make a long-time lease under our rapidly changing agricultural conditions, but when both parties are satisfied a lease than can be renewed year after year seems the most desirable. Intelligent and reasonable landlords and tenants can work together with little friction, provided the lease covers all points of importance and is just and definite in all its parts.

KINDS OF FARM LEASES

All farm leases in Minnesota fall into one of three classes—crop share rent, mixed crop and livestock share rent, and cash rent.

In any kind of a farm lease a few things are absolutely necessary: The names of the parties to the contract, the description of the land, the length of time the lease will run, the requirement that the land be farmed in a good and husbandlike manner, that improvements be properly cared for, and that the owner have the right to enter and take possession in case the renter fails to farm properly or to meet other provisions of the lease. They should also include provisions for remunerating the tenant for any unexhausted improvements made by him, as, for example, minor buildings supplied or fertilizer applied but unused.

Crop share leases are of two general kinds; those which give the owner one third of the small grain and those which give him one half.

THE ONE-THIRD CROP SHARE LEASE

In the one-third share lease the following is the commonly accepted plan:

(1) The landlord furnishes nothing but the land, which is usually very inadequately equipped with buildings.

(2) The tenant furnishes the machinery equipment, seed, and man and horse labor necessary to operate the farm, and pays all expenses except taxes on real estate and insurance on buildings.

(3) The owner gets one third of the small grain delivered at the market unless it is too far away, in which case he pays a certain rate per bushel for delivery to the market. In northwestern Minnesota the landlord frequently receives one fourth of the grain instead of one third.

(4) Any land used for corn, potatoes, or other cultivated crops is paid for in cash, and hay is usually put up by the tenant on half shares in the stack. If grass is seeded, the owner furnishes the seed.

This form of lease is largely an inheritance of pioneer farming and is gradually going out of use as the country develops and improvements are made. It is still used by absentee landlords or landlords who wish to relieve themselves of as much responsibility and risk as possible, but who prefer to rent on a share basis or are forced to do so.

THE ONE-HALF CROP SHARE LEASE

The most common one-half crop share lease provides that:

(1) The landlord furnish all seed, pay all taxes and insurance on real estate, and one half the cash expense for threshing.

(2) The tenant furnish all the horses, labor, machinery, and equipment necessary to operate the farm and pay one half the cash expense for threshing.

(3) The landlord receive one half of the grain either in the bin or delivered at the elevator, depending upon the distance to market.

(4) Hay be divided half and half in the stack and that the landlord furnish any grass seed sown.

(5) If corn is raised, the owner receive either one half in the field or two fifths if harvested and put into a crib by the tenant. Almost without exception the tenant pays cash for pasture and often for land put in cultivated crops. Some landlords in northwestern Minnesota furnish land for cultivated crops free of charge in order to keep the weeds under control.

One item which causes great dissatisfaction is feed for the horses. It is an almost universal practice that the horses be fed from undivided hay, but in the majority of leases the tenant is required to feed his own grain. As a result the tenant feels dissatisfied because the landlord does not share in all the feed expense for the horses, and the owner feels that his grain is being used if it happens to be stored on the farm. Many progressive landlords are giving leases that provide that the two parties share equally the cost of feed for horses. Where each party gets one half the crops, each should bear one half the expense. Using undivided feed for horses is a good method of equalizing the expense, as the ordinary crop share lease favors the landlord.

Another point which is handled in various ways is the raising of colts. Probably the most common method and also the most satisfactory one is for the landlord to pay the service fee and for the two parties to own the colts in common, and to feed them from undivided feed. One very successful farm manager in southern Minnesota gives his tenants the privilege of raising only enough colts to maintain their work horses, the colts and work horses being fed from undivided feed. Another landlord gets one-half interest in all colts raised by his tenants and considers this a satisfactory return for furnishing one half the feed for all the horses.

One advantage of the one-half crop share lease over the one-third crop share lease, from the viewpoint of a landlord, is that his furnishing the seed insures better seed and gives him an opportunity to prevent the introduction of noxious weeds through the seed used.

THE CROP AND STOCK SHARE LEASE

With the development of farming, the necessity and value of more livestock is becoming more and more appreciated.

(1) In the common form of crop and stock share lease the tenant supplies the machinery, the work horses, and the labor. The sales from crops are divided on a half-and-half basis as already described.

(2) With the introduction of cattle comes the silo, which necessitates special machinery. The landlord usually provides the engine and frequently the silage cutter, or meets the expense of hiring the power machinery when needed. Manure is produced that should be spread on the land. A manure spreader is almost a necessity and the landlord commonly has a half interest in it as well as in a cream separator if one is needed for cows owned in partnership.

(3) For beef cows, steers, hogs, sheep, or young cattle, growing in value, the most satisfactory and equitable arrangement is for the two parties to own them in common and to divide the proceeds from sales equally.

(4) The owner furnishes the pasture, which is offset by the tenant's labor, and each furnishes one half of the other feeds, whether raised or purchased.

(5) Often the tenant does not have capital to buy his share of stock and the owner furnishes all, but charges him interest on one half the value and deducts the purchase price of the stock when sold before making a division.

(6) Most landlords have a clause in the lease requiring the tenant to get the consent of the landlord before selling any livestock owned in common.

(7) Other cash items of farm expense are usually divided equally between landlord and tenant.

THE CROP AND STOCK SHARE LEASE, INCLUDING DAIRY CATTLE

(1) Dairy cattle require much more labor than other classes of livestock and it is customary for the landlord to furnish as compensation for the extra labor required all the cows and at least a half interest in the dairy bull.

(2) Returns from the sale of young cattle and dairy products are divided equally. The owner maintains his herd by selling the poorer cows and replacing them with heifers by buying out the tenant's half interest. The tenant may refuse to sell because he wishes to build up a herd of his own and thus part of the herd may gradually become owned in partnership.

(3) In justice to tenants, landlords should furnish good dairy cows since the man labor furnished by the tenant makes up a very large

proportion of the cost of keeping dairy cows, a cost which the landlord does not otherwise share. The advantage of good cows is that little more labor is required in caring for cows of high production than for those of low production. If tenants will not take proper care of dairy cows, they should not be furnished by the landlords, as neither party will be satisfied or secure profits.

(4) In order to keep good tenants on a dairy farm on a half share plan, it is becoming necessary to give them more liberal terms than has been the custom, and some landlords are paying a certain portion of the expense for hired labor.

THE CROP SHARE LEASE IN EVERYTHING EXCEPT LAND AND THE TENANT'S LABOR

(1) A lease providing that machinery and equipment and all livestock, including horses, be owned half and half and all returns be divided equally, is easily understood and is giving some landlords and tenants splendid satisfaction. It requires no special provision with regard to any one class of livestock and makes division of proceeds very simple.

(2) All expenses, including hired labor, are borne equally with the exception of insurance on farm buildings and taxes on real estate, which are paid by the landlord. The tenant furnishes the board for the hired men and in return receives milk, eggs, and farm produce for household use.

One landlord has operated his farm successfully for six years under this plan, and the following is a statement of business for 1916. If the landlord had borne none of the expense of hired labor, which many hold is a more just arrangement, he would have received 4.8 per cent on his investment instead of 4.3 per cent and the tenant would have received $1,259 instead of $1,489 as a labor income.

Investment	Tenant	Landlord
Real estate, 267 acres	.....	$33,375
Livestock	$3,324	3,324
Machinery	411	411
Feed and seed	1,030	1,030
Total	$4,765	$38,140

Receipts:				
Grain	$159		$159	
Cattle	1,486		1,486	
Cream	617		617	
Hogs	631		631	
Colts	246		246	
Poultry and miscellaneous	62		62	
Total receipts		$3,201		$3,201
Expenses:				
Labor	$230		$230	
Board of laborers	180		.....	
Threshing, shredding, and twine	72		72	
Gas, oil, etc	38		38	
Feed bought	369		369	
Seed bought	16		16	
Decrease of feed inventory	396		396	
Real estate, taxes, and insurance	.....		272	
Machinery repairs and depreciation	108		108	
Unclassified	65		65	
Total expenses		1,474		1,566
Receipts above expenses		$1,727		$1,635
Interest at 5 per cent on tenant's investment of $4,765		238		
Tenant's labor income		$1,489		
Landlord's percentage			4.3	

THE ONE-THIRD STOCK AND CROP SHARE LEASE

Another form of the stock and crop share lease merits consideration. It provides that:

(1) The landlord furnish the land and improvements, all the machinery and equipment except small tools, all the milk cows, all the horses, and two thirds of the hogs, sheep, and young cattle.

(2) The tenant pay for one third interest in the hogs, sheep, and young cattle and furnishes all labor.

(3) All farm expenses, including the seed purchased, twine, and threshing bills be borne, one third by the tenant and two thirds by the landlord. Any pasture needed in addition to that on the farm is paid for by the landlord.

(4) All receipts be divided on the basis of one third to the tenant and two thirds to the landlord.

This lease attracts capable young men without capital and is worthy of study by landlords who can keep in close touch with the business.

THE CASH LEASE

The cash lease is one of the oldest forms and its use is increasing rapidly, especially in the richer agricultural sections.

(1) The usual cash lease is very simple in form and gives the tenant almost absolute control of the land so long as he carries out the agreement.

(2) The up-to-date cash lease should require a crop rotation. It should make careful provision for the upkeep of the buildings and for the maintenance of soil fertility and the control of weeds.

Landlords do not always appreciate the fact that present land values are higher than returns from ordinary crops warrant and that they should not and can not justly expect to secure good tenants who will accept leases that will give them a very high rate of interest on their investment. Land values are and have been rising and a considerable part of the owner's profit comes from this source.

Landlords who are permanent investors and not temporary speculators are interested in the future welfare of their land. In order to care for the future welfare of the land and to insure continuous profits, at least three important problems must be considered in drawing up farm leases.

(1) The maintenance of fertility.

(2) The upkeep of improvements.

(3) The control of weeds, either to prevent them from getting a foothold or to eradicate those already present.

Fertility can be best and most cheaply maintained through the use of livestock for the production of manure and through proper crop rotations. Farm improvements will be most satisfactorily maintained by the landlord paying the tenant or some outside party for repairs that he deems necessary beyond the minor ones. Where weeds have gained a foothold the landlord must pay the tenant for extra work if they are to be eradicated. They can be prevented from gaining a foothold by crop rotations and good farming.

FORMS OF FARM LEASES

Following are suggested forms for three different kinds of farm leases; (1) A half-share crop lease, (2) a half-share crop and livestock lease, and (3) a cash lease.[3]

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[3] Since the court rulings on the relationship of landlord and tenant are somewhat confusing, the terms owner and operator will be used instead of landlord and tenant in the suggestions for forms of farm leases.

FORM FOR HALF-SHARE CROP LEASE

THIS AGREEMENT, Made this..........day of.................., 19...., by and between..............................hereinafter called the operator and..................................owner of the real estate hereinafter described

WITNESSETH, That the operator hereby agrees to and with the owner, for the consideration hereinafter named, to well and faithfully till and farm, during the season of farming in the year[1] 19...., 19...., 19...., 19...., and 19...., commencing...............19....and ending 19...., in a good and husbandlike manner, and according to the usual course of husbandry, the following described premises and land situated in the County of..

State of Minnesota, to-wit:..

(Description of land)..

....

....

....

....

ONE. The operator agrees to furnish at his own expense all horses, machinery, equipment, implements, and utensils necessary for the proper operation of said land (except as hereinafter otherwise provided for).[2]

TWO. The operator agrees to furnish all labor necessary to farm and cultivate said land.

THREE. The operator agrees to sow and plant on the said land such crops as may be agreed upon by the owner and operator, but the owner reserves the right of final decision in case of disagreement.

FOUR. The owner agrees to furnish all seed necessary to sow and plant said land and to pay one half the cash threshing bill.[3]

FIVE. The owner agrees to furnish half the feed for the horses necessary for the farm and to pay the service fee for all mares bred, the owner thereby receiving one half interest in all colts raised.[4]

SIX. In consideration of the faithful performance of all the stipulations of this contract, the owner agrees upon reasonable request thereafter made to give and deliver to the operator one half of the corn in the field, one half of the hay in the stack or barn, one half of the other grains in the granary or elevator, and one half of the fruit raised and secured upon said farm.[5] The operator agrees to deliver, with the exception of corn, the owner's share of grain and fruit to the market at ....free of charge.[6]

SEVEN. The operator agrees that he will not sell, remove or suffer to be removed without the written consent of the owner, any part of the crop raised or livestock in which the owner has an interest until final settlement, and until such settlement the title of all crops raised and of all livestock in which the owner has an interest shall remain with the owner.[7]

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[1] Leases are often made to cover only one year but are renewed from year to year.

[2] Frequently the owner pays half the cost of a manure spreader in order to encourage proper spreading of the manure.

[3] In some localities the owner also pays half the twine bill.

[4] Many variations relative to horse feed are found in different leases. Some provide that the operator feed undivided roughage, but his own grain. Others provide that the operator furnish half the seed as an offset to the owner for furnishing half of all horse feed.

[5] Some leases provide that the owner receive two fifths of the corn in the crib, while others provide for a cash rental charge per acre for all land in corn or other cultivated crops. Pasture land is usually on a cash basis and is frequently meadow land.

[6] If the farm is some distance from market, the operator is usually paid at a given rate for delivery of the owner's share of the crops to the market.

[7] If the owner advances money to the operator, a clause is desirable giving the owner the right to hold enough of the crops or livestock which would on division belong to the operator, to repay all advances made to the operator by the owner and interest thereon at..........per cent, also to pay for all indebtedness due the owner, by the operator, if any there be.

EIGHT. It is also agreed that in case the operator neglects or fails to perform any of the conditions and terms of this contract on his part to be done and performed, then the owner is hereby authorized and empowered to enter upon said premises and take full and absolute possession of the same, and he may do and perform all things agreed to be done by the operator remaining undone, and may retain or sell sufficient of the crops raised on said premises that would otherwise belong to the operator if he had performed the conditions hereof, to pay and satisfy all costs and expenses of every kind incurred in performing said contract, with interest at........per cent per annum, and the residue remaining, if any, of said crops, shall belong to the operator, after all conditions are fulfilled.

NINE. The operator agrees to keep up and maintain in good repair all buildings, stables, cribs, fences, and improvements on said premises and to return them in as good condition as at the commencement of the lease, natural wear and tear and unavoidable accidents excepted. The owner is to furnish material for repairs but the operator is to do the hauling of said material.[8] The operator also agrees to watch, care for, and protect the fruit and shade trees and to cut no green trees and to commit no waste or damage to said real estate or suffer any to be done.

TEN. The operator further agrees to sell no straw and to have it and all manure produced, hauled and spread on the fields most in need of it; and to mow the roadsides and keep all noxious weeds from going to seed and to prevent as far as possible the introduction of weeds not already present.[9]

ELEVEN. The operator agrees not to sublet any part of this land without first obtaining the written consent of the owner, and the owner reserves the right of free entry upon the premises for the purpose of making improvements thereon, to plow or till certain fields when the lease is to be terminated.[10]

TWELVE. It is further agreed that if the operator remains in possession of said premises after the expiration of the term for which they are hereby leased, such possession shall not be construed to be a renewal of this lease, but to be a lease which may be terminated upon ten days' notice given by the owner in writing, either delivered to the operator or sent to..........................in a sealed envelope, duly stamped and directed to..............................at..............................
which is hereby declared by...................to be..................
usual post-office address.[11]

THIRTEEN. And the owner agrees that the operator performing the covenants of this lease shall peacefully and quietly have, hold, and enjoy the said leased premises for the term aforesaid.

In Testimony Whereof both parties have hereunto set their hands and seals the day and year hereinbefore written.

Signed, sealed, and delivered in (Parties to contract)
the presence of ....Seal
(Witnesses) ....Seal
....Seal
....Seal

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[8] A clause providing that the owner pay for all improvements except minor ones may be substituted for the one requiring the operator to make them free of charge, also allowance may be provided for unexhausted improvements made by the operator, as fencing, buildings, and fertilizers.

[9] A clause may be included here in regard to the cropping or rotation system to be followed or the acreage of certain crops to be grown, also any agreement that may be made for the eradication of weeds which may infest the land.

[10] Many owners include a clause covering the conditions under which the operator can be asked to give up his lease in case the owner should sell the land.

The Minnesota state law does not make a lease binding on the purchaser of land for more than one year if the lease is not recorded and the lessee is not in possession of the land, unless the purchaser was cognizant of the lease and its provisions at the time the purchase was made.

[11] In some leases the clause relating to termination of lease provides that the lease will be considered as renewed for another year providing that neither party notifies the other in writing at some stated interval before the expiration of the lease of his intention to terminate the lease.

FORM FOR HALF-SHARE CROP AND LIVESTOCK LEASE

THIS AGREEMENT, Made this..........day of..................., 19...., by and between..................................hereinafter called the operator and..................................owner of the real estate hereinafter described

WITNESSETH, That the operator hereby agrees to and with the owner, for the consideration hereinafter named, to well and faithfully till and farm, during the season of farming in the year[1] 19...., 19...., 19...., 19...., and 19...., commencing................19....and ending 19...., in a good and husbandlike manner, and according to the usual course of husbandry, the following described premises and land situated in the County of...

State of Minnesota, to-wit:...

(Description of land)..

....

....

....

....

ONE. The operator agrees to furnish at his own cost and expense all machinery, horses, equipment, implements, and utensils necessary for the proper operation of said land (except as hereinafter otherwise provided for).

TWO. The operator agrees to furnish all labor necessary to farm and cultivate said land.

THREE. The operator agrees to sow and plant the said land in such crops as may be agreed upon by the owner and operator, but the owner reserves the right of final decision in case of disagreement.

FOUR. The operator agrees to market all crops, fruit, livestock, and livestock products, free of charge to the owner.

FIVE. The owner agrees to furnish all seed necessary to sow and plant said land and to pay one half the cash threshing bill.[2]

SIX. The owner agrees to furnish not less than .... cows and a purebred dairy bull, and one half of such number of brood sows, young cattle, feeding cattle, and sheep as may be agreed upon.[3]

SEVEN. The owner agrees to furnish one half the feed and all the pasture required for the livestock kept and used on said land except poultry, and to pay the service fee for all mares bred, the owner thereby receiving one half interest in all colts raised.[4]

EIGHT. The owner agrees to furnish power and a silage cutter for putting up silage and one half the cost of a cream separator and a manure spreader.

NINE. The owner agrees to pay the tax on real estate and insurance on buildings, one half the insurance and tax on the personal property of the farm, and one half the veterinary bills.

TEN. The owner agrees that the operator may have without charge such amounts of milk and cream as are necessary for household use, and a garden of sufficient size to provide for household consumption,[5] also that the operator may keep and feed at his own expense, not more than.................hens.[6]

[1] Leases are frequently made to cover only one year, but are renewed from year to year.

[2] In some localities the owner also pays half the twine bill.

[3] Where dairy cows are kept, man labor is a very large item of expense and some leases provide that the owner pay a part of the cost of hired labor.

[4] Many variations relative to horse feed are found in different leases. Some provide that the operator feed undivided roughage, but his own grain. Other leases provide that the operator furnish half the seed as an offset to the owner for furnishing one half of all horse feed.

[5] Where there is wood on a farm, a clause should be inserted covering its use by the operator for fuel.

[6] Some leases provide that poultry be owned jointly and fed as other stock and that sales of eggs and poultry be divided equally.

ELEVEN. The owner is to receive as rent one half of all products raised or produced on the above described property, one half the increase from all livestock jointly owned, and one half the returns from all sales of crops, fruits, livestock products, and livestock jointly owned, except as hereinbefore or hereinafter provided for.

TWELVE. The operator further agrees that he will not sell, remove, or suffer to be removed without the consent of the owner, any part of the crop raised or livestock in which the owner has an interest until final settlement, and until final settlement the title of all crops raised and of all livestock in which the owner has an interest shall remain with the owner.[7]

THIRTEEN. It is also agreed that in case the operator neglects or fails to perform any of the conditions and terms of this contract on his part to be done and performed, then the owner is hereby authorized and empowered to enter upon said premises and take full and absolute possession of the same, and he may do and perform all things agreed to be done by the operator, remaining undone, and to retain or sell sufficient of the crops raised on said premises that would otherwise belong to the operator if he had performed the conditions hereof, to pay and satisfy all costs and expense of every kind incurred in performing said contract, with interest at .... per cent per annum, and the residue remaining, if any, of said crops, shall belong to the operator after all conditions are fulfilled.

FOURTEEN. The operator agrees to keep up and maintain in good repair all buildings, stables, cribs, fences, and improvements on said premises and to return them in as good condition as at the commencement of the lease, natural wear and tear and unavoidable accidents excepted. The owner is to furnish the material but the operator is to do the hauling of said material.[8] The operator also agrees to watch, care for, and protect the fruit and shade trees and to cut no green trees and to commit no waste or damage to said premises or suffer any to be done.

FIFTEEN. The operator further agrees to sell no straw, but to have it and all manure produced, scattered on the fields most in need of it; and to mow the roadside and keep all noxious weeds from going to seed and to prevent the introduction of weeds not already present.[9]

SIXTEEN. The operator agrees not to sublet any part of said land without first obtaining the consent of the owner, and the owner reserves the right of free entry upon the premises for the purpose of making improvements thereon, and to plow or till certain fields when the lease is to be terminated.[10]

SEVENTEEN. In case the owner and operator fail to agree in regard to any clause of the lease, or in regard to the manner of making a division of property jointly owned, then the matter in controversy shall be referred to a board of three men, one selected by the operator, one by the owner, and a third by the two so chosen. Both parties agree to abide by and accept any decision rendered by the three chosen arbiters.

EIGHTEEN. It is further agreed that if the operator remains in possession of said premises after the expiration of the term for which they are hereby leased, such possession shall not be construed to be a renewal of this lease, but to be a lease which may be terminated upon ten days' notice given by the landlord in writing, either delivered to the operator or sent to .... in a sealed envelope, duly stamped and directed to .... at .... which is hereby declared by .... to be .... usual postoffice address.[11]

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[7] When the owner advances money to the operator a clause is desirable giving the owner the right to hold enough of the crops or livestock which would on division belong to the operator, to repay all advances made to the operator by the owner and interest thereon at..........per cent, also to pay all indebtedness due the owner by the operator, if any there be.

[8] A clause providing that the owner pay for all improvements except minor ones may be substituted for the one requiring the operator to make them free of charge, also allowance may be provided for unexhausted improvements, as fences, buildings, and fertilizers.

[9] A clause may be included here in regard to the cropping or rotation system to be followed or the acreage of certain crops to be grown, also any agreement that may be made for the eradication of weeds which may infest the land.

[10] Many owners include a clause covering the conditions under which the operator can be asked to give up his lease in case the owner should sell the land. The Minnesota state law does not make a lease binding on the purchaser of land for more than one year where the lease is not recorded and the lessee is not in possession of the land, unless the purchaser was cognizant of the lease and its provisions at the time the purchase was made.

NINETEEN. And the owner agrees that the operator on performing the covenants of this lease shall peacefully and quietly have, hold, and enjoy the said leased premises for the term aforesaid.

In Testimony Whereof both parties have hereunto set their hands and seals the day and year hereinbefore written.

Signed, sealed, and delivered in the presence of (Witnesses)	(Parties to contract)
	............................Seal
	............................Seal
....	............................Seal
....	............................Seal

---

[11] In some leases the clause relating to termination provides that the lease will be considered as renewed for another year providing neither party notifies the other in writing at some stated interval before the expiration of the lease of his intention to terminate the lease.

EVERYTHING SHARED HALF AND HALF EXCEPT LAND AND THE OPERATOR'S LABOR.

If the owner and operator wish to have a half-and-half crop and livestock share lease, the following paragraph may be substituted for that part of the preceding lease included between description of the land and the clause relating to the tenant's agreement not to sell or to remove crops without obtaining the owner's consent.

The owner and operator each agree to furnish one half of all machinery, equipment, and livestock, including work horses used and kept on the said farm. Each agrees to bear one half of all farm expenses including hired farm labor, except that the owner will pay all the taxes and insurance on the real estate and the operator will board the hired labor without charge to the owner.

The owner is to receive as rent one half the increase or one half the sales from all livestock, livestock products, crops, or other farm products raised or produced on said farm, except that the operator may use without charge such amounts of milk, cream, butter, eggs, and farm produce as may be necessary for use in the household.

If a lease provides that all farm expenses and receipts be borne equally by the owner and operator except that the owner meet the taxes, insurance, and upkeep expenses on the real estate, the only question as to equality of division of expenses is the relation that the operator's labor bears to the rental value of the landlord's property.

FORM FOR CASH LEASE

THIS AGREEMENT, made this..............day of.............. 19....by and between......................hereinafter called the operator and..........................owner of the real estate hereinafter described

WITNESSETH, that the operator hereby agrees to and with the owner, for the consideration hereinafter named, to well and faithfully till and farm, during the season of farming in the year[1] 19...., 19...., 19...., 19...., and 19...., commencing.................... 19...., and ending 19...., in a good and husbandlike manner, and according to the usual course of husbandry, the following described premises and land situated

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[1] The leases are frequently made to cover only one year, but are often renewed from year to year.

in the County of........................State of Minnesota, to wit:
(Description of land)...
....
....
....

The operator agrees to and with the owner to pay as rent for the above mentioned premises each year during the term of this lease, the sum of........................DOLLARS on the..................
day of....................19...., 19...., 19...., 19....[2]
....
....
....

ONE. The operator agrees to keep up and maintain in good repair all buildings, stables, cribs, fences, and improvements on said premises, and to return them in as good condition as at the commencement of the lease, natural wear and tear and unavoidable accidents excepted. The owner is to furnish the material for repairs, but the operator is to do the hauling of said material.[3] The operator agrees to watch, care for, and protect the fruit and shade trees thereon and to cut no green trees and to commit no waste or damage to said premises or suffer any to be done.

TWO. The operator agrees to sell no straw, and to have it and all manure produced, hauled and spread on the fields most in need of it; and to mow the roadsides and keep all noxious weeds from going to seed and to prevent the introduction of weeds not already present,[4] and to leave as many acres of land plowed on giving up possession of the premises at the termination of this lease as were plowed at the time of taking possession of the premises.

THREE. The operator agrees not to sublet any part of this farm without first obtaining the consent of the owner, and the owner reserves the right of free entry upon the premises for the purpose of making improvements thereon, or plowing or tilling certain fields when the lease is to be terminated.[5]

FOUR. It is agreed that if the operator fails to make the above mentioned payments as herein specified, or to pay any of the aforesaid rent when due, or fails to fulfill any of the covenants of this lease, then and in that case the owner may re-enter and take possession of the above rented premises, and hold and enjoy the same without such re-entering working a forfeiture of the rents to be paid by the operator for the full term of this lease.

FIVE. It is further agreed that if the operator remains in possession of said premises after the expiration of the term for which they are hereby leased, such possession shall not be construed to be a renewal of this lease, but to be a lease which may be terminated upon ten days' notice given by the owner in writing, either delivered to the operator or sent to............................in a sealed envelope, duly stamped and directed to........................at........................

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[2] A memorandum of promissory notes and chattel mortgage required by owner to insure payment of rent may be included, also a provision for any changes in the amount of rent to be paid in event the lease is renewed.

[3] A clause providing that the owner pay for all improvements except minor ones may be substituted for the one requiring the tenant to make them free of charge, also allowance may be provided for unexhausted improvements added by the operator, as fencing, buildings, and fertilizers.

[4] A clause may be included here in regard to the cropping or rotation system to be followed or the acreage of certain crops to be grown, also any agreement that may be made for the eradication of weeds which may infest the land.

[5] Many owners include a clause covering the conditions under which the operator can be asked to give up his lease in case the owner should sell the land. The Minnesota state law does not make a lease binding on the purchaser of land for more than one year if the lease is not recorded and the lessee is not in possession of the land, unless the purchaser was cognizant of the lease and its provisions at the time the purchase was made.

which is hereby declared by....................to be................ usual post-office address.[6]

SIX. And the owner agrees that the operator upon paying the rent and performing the covenants of this lease shall peacefully and quietly have, hold, and enjoy the said leased premises for the term aforesaid.

In Testimony Whereof both parties have hereunto set their hands and seals the day and year hereinbefore written.

Signed, sealed, and delivered in the presence of (Witnesses)	(Parties to contract)
	...........................Seal
	...........................Seal
....	...........................Seal
....	...........................Seal

---

[6] In same leases the clause relating to termination of lease provides that the lease will be considered as renewed for another year provided neither party notifies the other in writing at some stated interval before the expiration of the lease of his intention to terminate the lease.

EQUITABLE BASIS FOR SHARE LEASES

The proper basis for a fair and equitable share lease is that each party share in the products of the farm in the proportion that he shares in the cost of production. The shares that the landlord and tenant bear in the cost of producing wheat, oats, barley, hay, corn husked from the standing stalks, corn cut, shocked, and stacked, and corn cut for silage, are given on the acre basis in Tables VI to XII, following in general the provisions of the foregoing lease. The calculations are based on present prices, using the data from Northfield, Rice County, as representative of southern Minnesota conditions, and data from Halstad, Norman County, as representative of western and northwestern conditions.[4]

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[4] The hour requirements for crop production are taken from Minn. Agr. Exp. Sta. Bull. 157, "Labor requirements of crop production," by T. P. Cooper, F. W. Peck, and Andrew Boss. 1916. The hour cost of horse and man labor is based on recent accounting data on file in the section of cost accounting of the Division of Agronomy and Farm Management. The other costs are based on Minn. Agr. Exp. Sta. Bull. 145, "Cost of producing Minnesota farm products, 1908-1912," by F. W. Peck. 1914. The data in this bulletin are modified to meet present conditions in accordance with the recent data of the section of cost accounting mentioned above.

TABLE VI

COST OF PRODUCING WHEAT AND DIVISION OF EXPENSE BETWEEN LANDLORD AND TENANT
FALL-PLOWED AND STACK-THRESHED

	Northfield					Halstad				
	Cost per acre	Usual one-half share system		Usual one-third share system*		Cost per acre	Usual one-half share system		Usual one-third share system*	
		Landlord's expense	Tenant's expense	Landlord's expense	Tenant's expense		Landlord's expense	Tenant's expense	Landlord's expense	Tenant's expense
Seed, 1¼ bu. at $2	$2.50	$2.50	....	....	$2.50	$2.50	$2.50	....	....	$2.50
Man labor, 24 cents per hour	4.08 (17 hrs.)	....	$4.08	....	4.08	2.88 (12 hrs.)	....	$2.88	....	2.88
Horse labor, 15 cents per hour	4.35 (29 hrs.)	1.63	2.72	....	4.35	4.20 (28 hrs.)	1.58	2.62	....	4.20
Twine	0.32	....	0.32	....	0.32	0.36	....	0.36	....	0.36
Cash threshing	0.56	0.28	0.28	....	0.56	0.60	0.30	0.30	....	0.60
Machinery	1.50	....	1.50	....	1.50	0.99	....	0.99	....	0.99
Land rental	4.50	4.50	....	$4.50	....	3.00	3.00	....	$3.00	....
General expense	0.77	0.50	0.27	0.50	0.27	0.65	0.40	0.25	0.40	0.25
Total	$18.58	$9.41	$9.17	$5.00	$13.58	$15.18	$7.78	$7.40	$3.40	$11.78

* The usual one-third share system is the one by which the landlord gets one third of the crop.

TABLE VII

Cost of Producing Oats and Division of Expense Between Landlord and Tenant Fall-Plowed and Stack-Threshed

	Northfield					Halstad				
	Cost per acre	Usual one-half share system		Usual one-third share system*		Cost per acre	Usual one-half share system		Usual one-third share system*	
		Landlord's expense	Tenant's expense	Landlord's expense	Tenant's expense		Landlord's expense	Tenant's expense	Landlord's expense	Tenant's expense
Seed, 2½ bu. at 85 cents	$2.12	$2.12	....	....	$2.12	$2.12	$2.12	....	....	$2.12
Man labor, 24 cents per hour	3.60 (15 hrs.)	....	$3.60	....	3.60	3.12 (13 hrs.)	....	$3.12	....	3.12
Horse labor, 15 cents per hour	4.20 (28 hrs.)	1.58	2.62	....	4.20	4.35 (29 hrs.)	1.64	2.71	....	4.35
Twine	0.38	....	0.38	....	0.38	0.39	....	0.39	....	0.39
Cash threshing	0.72	0.36	0.36	....	0.72	0.75	0.38	0.37	....	0.75
Machinery	1.50	....	1.50	....	1.50	0.99	....	0.99	....	0.99
Land rent	4.50	4.50	....	$4.50	....	3.00	3.00	....	$3.00	....
General expense	0.80	0.50	0.30	0.50	0.30	0.64	0.40	0.24	0.40	0.24
Total	$17.82	$9.06	$8.76	$5.00	$12.82	$15.36	$7.54	$7.82	$3.40	$11.96

* The usual one-third share system is the one by which the landlord gets one third of the crop.

TABLE VIII

COST OF PRODUCING BARLEY AND DIVISION OF EXPENSE BETWEEN LANDLORD AND TENANT
FALL-PLOWED AND STACK-THRESHED

	Northfield					Halstad				
	Cost per acre	Usual one-half share system		Usual one-third share system*		Cost per acre	Usual one-half share system		Usual one-third share system*	
		Landlord's expense	Tenant's expense	Landlord's expense	Tenant's expense		Landlord's expense	Tenant's expense	Landlord's expense	Tenant's expense
Seed, 1¾ bu. at $2	$3.50	$3.50			$3.50	$3.50	$3.50			$3.50
Man labor, 24 cents per hour	4.20 (17.5 hrs.)		$4.20		4.20	3.48 (14.5 hrs.)		$3.48		3.48
Horse labor, 15 cents per hour	4.35 (29 hrs.)	1.63	2.72		4.35	4.50 (30 hrs.)	1.69	2.81		4.50
Twine	0.40		0.40		0.40	0.36		0.36		0.36
Cash threshing	0.73	0.36	0.37		0.73	0.85	0.42	0.43		0.85
Machinery	1.50		1.50		1.50	0.99		0.99		0.99
Land rental	4.50	4.50		$4.50		3.00	3.00		3.00	
General expense	0.78	0.50	0.28	0.50	0.28	0.61	0.40	0.21	0.40	0.21
Total	$19.96	$10.49	$9.47	$5.00	$14.96	$17.29	$9.01	$8.28	$3.40	$13.89

* The usual one-third share system is the one by which the landlord gets one third of the crop.

TABLE IX

COST OF PRODUCING CORN HUSKED FROM STANDING STALKS AND DIVISION OF EXPENSE BETWEEN LANDLORD AND TENANT

	Northfield					Halstad				
	Cost per acre	Usual one-half share system		Corn harvested by tenant, landlord's share two fifths		Cost per acre	Usual one-half share system		Corn harvested by tenant, landlord's share two fifths	
		Landlord's expense	Tenant's expense	Landlord's expense	Tenant's expense		Landlord's expense	Tenant's expense	Landlord's expense	Tenant's expense
Seed	$1.00	$1.00	....	$1.00	....	$1.00	$1.00	....	$1.00	....
Man labor up to harvesting, 24 cents per hour	4.32 (18 hrs.)	....	$4.32	....	$4.32	4.08 (17 hrs.)	....	$4.08	....	$4.08
Man labor in harvesting, 24 cents per hour	2.88 (12 hrs.)	1.44	1.44	....	2.88	3.12 (12 hrs.)	1.56	1.56	....	3.12
Horse labor up to harvesting, 15 cents per hour	5.78 (38.5 hrs.)	2.17	3.61	2.17	3.61	6.45 (43 hrs.)	2.42	4.03	2.42	4.03
Horse labor in harvesting, 15 cents per hour	2.25 (15 hrs.)	1.12	1.13	0.85	1.40	2.25 (15 hrs.)	1.12	1.13	0.84	1.41
Machinery	1.90	....	1.90	....	1.90	1.45	....	1.45	....	1.45
Land rental	4.50	4.50	....	4.50	....	3.00	3.00	....	3.00	....
General expense	1.32	0.50	0.82	0.50	0.82	1.10	0.40	0.70	0.40	0.70
Total	$23.95	$10.73	$13.22	$9.02	$14.93	$22.45	$9.50	$12.95	$7.66	$14.79

TABLE X

COST OF PRODUCING TAME HAY AND DIVISION OF EXPENSE BETWEEN LANDLORD AND TENANT

	Northfield			Halstad		
	Cost per acre	Usual one-half share system		Cost per acre	Usual one-half share system	
		Landlord's expense	Tenant's expense		Landlord's expense	Tenant's expense
First Crop						
Seed........................	$0.82	$0.82	....	$0.82	$0.82	....
Man labor, 24 cents per hour .	3.00 (12.5 hrs.)	....	$3.00	3.12 (13 hrs.)	....	$3.12
Horse labor, 15 cents per hour.	1.80 (12 hrs.)	0.68	1.12	2.10 (14 hrs.)	0.79	1.31
Machinery.................	1.76	....	1.76	1.17	....	1.17
Land rent..................	4.50	4.50	....	3.00	3.00	....
General expense.............	0.62	0.50	0.12	0.72	0.40	0.32
Total................	12.50	6.50	6.00	10.93	5.01	5.92
Second Crop						
Man labor, 24 cents per hour..	2.04 (8.5 hrs.)	....	2.04	No data	available	
Horse labor, 15 cents per hour.	1.28 (8.5 hrs.)	0.48	0.80	....	....	....
General expense.............	0.49	....	0.49	....	....	....
Total................	$16.31	$6.98	$9.33	....	....	....

TABLE XI

COST OF PRODUCING CORN AND DIVISION OF EXPENSE BETWEEN LANDLORD AND TENANT CUT, SHOCKED, AND STACKED

	Northfield			Halstad		
	Cost per acre	Usual one-half share system		Cost per acre	Usual one-half share system	
		Landlord's expense	Tenant's expense		Landlord's expense	Tenant's expense
Seed........................	$1.00	$1.00	....	$1.00	$1.00	....
Man labor, 24 cents per hour..	8.16 (34 hrs.)	....	8.16	7.92 (33 hrs.)	....	$7.92
Horse labor, 15 cents per hour.	8.10 (54 hrs.)	3.04	5.06	7.95 (53 hrs.)	2.98	4.97
Twine.....................	0.54	....	0.54	0.49	....	0.49
Machinery..................	2.11	....	2.11	2.00	....	2.00
Land rental.................	4.50	4.50	....	3.00	3.00	....
General expense.............	1.32	0.50	0.82	1.10	0.40	0.70
Total................	$25.73	$9.04	$16.69	$23.46	$7.38	$16.08

TABLE XII

COST OF PRODUCING CORN SILAGE AND DIVISION OF EXPENSE BETWEEN LANDLORD AND TENANT

	Northfield			Halstad		
	Cost per acre	Usual one-half share system		Cost per acre	Usual one-half share system	
		Landlord's expense	Tenant's expense		Landlord's expense	Tenant's expense
Seed	$2.14	$2.14	....	$1.94	$1.94	....
Man labor, 24 cents per hour	8.16 (34 hrs.)	....	$8.16	7.56 (31.5 hrs)	....	$7.56
Horse labor, 15 cents per hour	8.40 (56 hrs.)	3.15	5.25	9.68 (64.5 hrs)	3.63	6.05
Twine	0.72	....	0.72	0.72	....	0.72
Coal	0.82	0.41	0.41	0.44	0.22	0.22
Power machine	1.32	1.32	....	1.46	1.46	....
Farm machinery and ensilage cutter	2.38	....	2.38	2.29	....	2.29
Land rental	4.50	4.50	....	3.00	3.00	....
General expense	0.91	0.50	0.41	1.35	0.40	0.95
Total	$29.35	$12.02	$17.33	$28.44	$10.65	$17.79

Calculations made for present conditions indicate that three fourths of the expense of maintaining a work horse is the cost of feed, and on the assumption that the owner is furnishing one half the horse feed, he is charged one half of this or three eighths of the total cost as his share in the cost of horse labor. Recent prices show that twine has doubled in price since the figures in Bulletin 145 were compiled, also that the price of machinery has advanced 50 per cent. Data on hand indicate that taxes and insurance are approximately 50 cents an acre at Northfield and 40 cents at Halstad. This part of the general expense is charged to the owner.

Under the one-third share system for small grain there is a large variation from one locality to another in the proportion of the cost borne by landlord and tenant. The landlord contributes more than one third on high-priced land and less than one third on lower priced land. Under the half-share system it will be noted that the landlord contributes in most instances a little more than the tenant in the production of oats, wheat, and barley. It is not desirable to change the division of crops from the half-share basis, but the cost of production may easily be equalized by having the tenant bear a portion of the cost of seed. Where a considerable acreage of corn is grown, such an equalization would not be so applicable, for altho the landlord bears more than one half of the cost of production of small grain on the half-share basis, the tenant bears a much larger proportion of the cost of producing corn. As there are usually three or four times as many acres of small grain as of corn, the larger proportion of expense to the landlord on small grains tends to equalize the larger proportion of expense to the tenant on the corn crop.

The unequal division of the costs in producing corn accounts in a large measure for the cash renting of corn land where the other crops are on a share basis. If the corn crop is divided on the half-and-half share basis there is a decided advantage in favor of the landlord, ranging from $2.49 for husked corn, at Northfield, to $8.70 for corn cut, shocked, and stacked, at Halstad. If corn is husked and cribbed by the tenant and he receives three fifths of the crop, the division is much more nearly in line with his proportion of the cost of production. The tenant also gets the use of the cornstalks, which are usually considered worth at least $1 per acre if the tenant has cattle to feed.

If livestock is fed on a share basis and corn is used for silage or is cut, shocked, and stacked, or fed from the bundle, the tenant contributes considerable more than the landlord and should be compensated in some way if the crop is shared on the half-and-half basis. This may easily be done in putting up silage by the landlord paying for part of the man labor required.

Clover and timothy hay put up by the tenant on a half-share basis gives nearly an equal division of the expense for the first crop on the higher-priced lands. If more than one crop is cut, it is decidedly in favor of the landlord since he has little or no additional expense. It must be remembered, however, that the landlord must stand all the risk of crop failure while the tenant's only expense is for harvesting, and for this reason a half share division of the crop is much more just than would appear on first reading the data given in Table X.

TABLE XIII

ANNUAL COST OF MAINTAINING A DAIRY COW[*]

	Northfield			Halstad		
	Total	Owner	Tenant	Total	Owner	Tenant
Feed-grain	$22.92	$11.46	$11.46	$20.34	$10.17	$10.17
Roughage	24.69	12.34	12.35	37.20	18.60	18.60
Silage	12.06	6.03	6.03	8.89	4.45	4.44
Pasture	15.00	15.00	....	9.00	9.00	....
Man labor, 24 cents	34.80 (145 hrs.)	....	34.80	38.40 (160 hrs.)	....	38.40
Horse labor, 15 cents	6.00 (40 hrs.)	2.25	3.75	2.55 (17 hrs.)	0.96	1.59
Cow cost, Dep., Int., Taxes, Ins	14.56	14.56	....	11.74	11.74	....
Sire	4.00	2.00	2.00	4.00	2.00	2.00
Equipment	0.52	....	0.52	1.01	....	1.01
Bedding	4.00	2.00	2.00	4.00	2.00	2.00
General expense	0.78	0.39	0.39	0.36	0.18	0.18
Total	$143.33	....	....	$137.49	....	....
Overhead at 10 per cent	14.34	7.17	7.17	13.75	7.01	7.02
Total	$157.67	$73.20	$80.47	$151.24	$66.11	$85.41

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[*] Data taken from Minn. Agr. Exp. Sta. Bull. 173, "The cost of milk production," by F. W. Peck and Andrew Boss. 1918.

TABLE XIV

SUMMARY OF USUAL HALF-SHARE RENTAL SYSTEM AND THE SYSTEM WHERE EVERYTHING IS SHARED HALF AND HALF*

	Northfield					Halstad				
	Total cost	Usual one-half share system		Everything shared half and half		Total cost	Usual one-half share system		Everything shared half and half	
		Landlord's expense	Tenant's expense	Landlord's expense	Tenant's expense		Landlord's expense	Tenant's expense	Landlord's expense	Tenant's expense
Wheat	$18.58	$9.41	$9.17	$10.77	$7.81	$15.18	$7.78	$7.40	$8.57	$6.61
Oats	17.82	9.06	8.76	10.51	7.31	15.36	7.54	7.82	8.60	6.76
Barley	19.96	10.49	9.47	11.43	8.53	17.29	9.01	8.28	9.47	7.82
Tame hay (one crop)	12.50	6.50	6.00	8.00	4.50	10.93	5.01	5.92	6.38	4.55
Corn, husked from standing shocks	23.95	10.73	13.22	12.67	11.28	22.45	9.50	12.95	11.12	11.32
Corn, cut, shocked, and stacked	25.73	9.04	16.69	13.33	12.40	23.46	7.38	16.08	11.45	12.01
Corn silage	29.35	12.02	17.33	15.13	14.22	28.44	10.65	17.79	14.03	14.41
Dairy cow	153.67	73.20	80.47	75.64	78.03	151.24	65.97	85.27	70.52	80.72

---

* The landlord's half share of the cash labor is considered as one quarter of all man labor.

Tables VI to XII and the discussion referring to the crops under the half-share crop lease will also apply to the same crops under the half-share crop and livestock lease. The proper division of expenses under a lease including livestock is, however, more difficult to secure. Under a half-share lease where the landlord furnishes all the dairy cows, he contributes less than one half the cost of maintenance. This holds true in the well-established dairying regions, as at Northfield, where the cows were valued at $100 per head and two acres of pasture at $15. At Halstad, where the cows were valued at $75 per head and two acres of pasture at $9, the proportion contributed by the landlord was much smaller, as is shown in Table XIII. No building charge is included in the landlord's expense as this is included in the rental charge on land. The overhead charge has been divided equally, since there is no way to calculate how much each party contributes. The figures in this table show why some landlords are finding it necessary to contribute a part of the expense of hired labor. Otherwise the tenant stands much more than half the expense of maintaining the dairy herd.

The relative amount contributed by the landlord and tenant to the cost of raising beef cattle, hogs, and sheep on a half-share basis can not be easily calculated, but the furnishing of pasture by the landlord is considered as an offset to the labor furnished by the tenant. The landlord frequently feels he is contributing further by furnishing better housing facilities, which tend to increase his share of the cost.

On the basis of the calculation made in Tables VI to XIII, the proportion of expense borne by the landlord and tenant for crops and dairy cows is summarized in Table XIV. This table gives a summary of the results under the usual half-share system, and also under the system where everything is shared half and half. Under this latter system the landlord bears considerably more than half of the cost of producing small grain, but the cost of producing corn is as near equal as a share rental system could be expected to provide. The tenant still bears more than half of the cost of maintaining the dairy cows, but the difference is not so wide as where the usual half-share system is followed. No one share system will meet all conditions. At Northfield, where land rent is relatively high, all other costs being the same, the owner furnishes more toward the production of an acre of crops than at Halstad, where rents are 50 per cent lower.

Forms of leases for various types of farming have been suggested in the foregoing pages and also data on cost of production have been given. With these to serve as a guide, both landlord and tenant are in a better position to draw up just and satisfactory leases.

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BULLETIN 179 NOVEMBER 1918

The University of Minnesota
AGRICULTURAL EXPERIMENT STATION

THE COST OF PRODUCING MINNESOTA FIELD CROPS, 1913-1917

BY

F. W. PECK

DIVISION OF AGRONOMY AND FARM MANAGEMENT

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* On leave of absence.

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SUMMARY

1. The crop yields on the farms concerned in this investigation were above the average for the state by the following amounts per acre: wheat 3.8 bushels, oats 5.9 bushels, barley 0.7 bushel, rye 6.3 bushels, corn 5.4 bushels, and potatoes 17.3 bushels. See Table II.

2. The average monthly cost of board for 1913-1917 at Halstad amounted to $14.96, or 50 cents per day. At Cokato the board cost $16.02 per month, or 53 cents per day. The average daily cost for all farms was 52 cents. See Table VI.

3. The average wage rate per hour for labor hired by the month for the years 1913-1917 for the seven crop months (April to October) was 15.3 cents at Halstad; and 15.7 cents at Cokato. This was an increase of 12 per cent over the previous five-year period. The cost of labor was 21 per cent higher in 1917 than in 1912. Table VII.

4. The five-year average annual cost of maintaining a farm work horse at Halstad was $110.50 and at Cokato $113.36. In 1917 the cost was $151.56 at Halstad and $128 at Cokato. At Halstad the horses averaged 941 hours of labor annually and 3.14 daily. At Cokato they worked 974 hours annually and 3.25 daily. The cost per hour was slightly more than 11 cents in each locality. In 1917 the rate per hour was 17 cents at Halstad and 13.6 cents at Cokato. See Tables IX, X, and XI.

5. For the period 1913-1917 the average annual depreciation of machinery was 7.3 per cent for all machines. The acre cost of machinery for various crops varied from $1.26 on small grain to $3.09 on corn silage. See Tables XII, XIII, and XIV.

6. For the amount and cost of seed and twine used per acre for the various crops, see Tables XV and XVI.

7. The average cost of labor per acre for spring plowing was $1.91 in each locality and for fall plowing, $2.04. See Table XVIII.

8. The total cost per acre including land rental, of producing the principal field crops for the period 1913-1917, was as follows: Spring wheat $16.33, oats $16.54, barley $15.81, rye $16.66, corn $19.28, fodder corn $19.03, corn silage $23.53, potatoes $45.37, flax $18.99, clover and timothy hay, one cutting, $11.22, alfalfa hay, 3 cuttings, $16.59, wild hay $8.67, timothy seed $7.54, and clover seed $9.61. These costs include all labor of the farmer and his family at hired laborer's wages. See Table XXXVIII.

9. By comparing the cost per acre for the five-year period, 1908-1912, with the cost during 1913-1917 it was found that there was an increase in cost of the principal crops as follows: wheat 40 per cent,

oats 28, barley 31, corn 25, silage 16, tame hay 49, wild hay 19, clover seed 15. See Table XXXIX.

10. The average farm prices Dec. 1, 1913 to 1917 were: wheat $1.26 per bushel, oats 43 cents, barley 70 cents, rye $1.02, flax $1.92, corn 71 cents, potatoes 69 cents, and hay $7.64 per ton. At these prices it was necessary to obtain the following yields per acre in order to cover the entire cost of production: wheat 13 bushels, oats 34.4, barley 21.6, rye 15, flax 9.9, corn 27, potatoes 66, and hay 1.4 tons. See Table XLI.

THE COST OF PRODUCING FIELD CROPS, 1913-1917

By F. W. Peck

It is becoming more and more apparent that earnings on land must come from production and not from speculation. This means the adoption of better farming methods, more attention to productive enterprises, and closer application of business principles to the farm business. The nature of the farming business is such that it may be more or less accurately classified as an individually managed business, and the operator should know all the facts possible about his particular business.

At best there are certain handicaps under which he must labor and over which he, as an individual, has little, if any, control. These are (1) Climatic and weather conditions, (2) Diseases and accidents, (3) Violent and sudden market fluctuations.

As these are inherent risks of the farming business it becomes all the more necessary for the operator to know all the facts possible in order to minimize the chances for loss or failure. This knowledge can be obtained only by keeping a record of the various transactions that are principal in determining the financial result. It seems essential for the farm operator to study the factors of cost of production and to make his own application if profitable cropping and livestock systems are to be maintained. The principal value of a study of the cost of production is to give a basis for comparing farm enterprises so as to select profitable units for a farm business.

The data here presented are a continuation of the results of the cost studies started in 1902, the previous results of which have been published in Minnesota Agricultural Experiment Station Bulletins Nos. 97, 117, 124, 145, 157, 161, and 173.[1]

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[1] Hays, W. M., and Parker, E. C. The cost of farm products. U. S. Dept. of Agr., Bureau of Statistics, Bull. 48, and Minn. Agr. Exp. Sta. Bull. 97. 1906.

Parker, E. C., and Cooper, Thomas. The cost of producing Minnesota farm products. U. S. Dept. of Agr., Bureau of Statistics, Bull. 73, and Minn. Agr. Exp. Sta. Bull. 117. 1910.

Cooper, Thomas. The cost of Minnesota dairy products. U. S. Dept. of Agr., Bureau of Statistics, Bull. 88, and Minn. Agr. Exp. Sta. Bull. 124. 1911.

These bulletins are out of print and no longer available.

Peck, F. W. The cost of producing Minnesota farm products, 1908-1912. Minn. Agr. Exp. Sta. Bull. 145. 1915.

Cooper, T. P., Peck, F. W., and Boss, Andrew. Labor requirements of crop production. Minn. Agr. Exp. Sta. Bull. 157. 1916.

Boss, Andrew, Peck, F. W., and Cooper, T. P. Labor requirements of livestock. Minn. Agr. Exp. Sta. Bull. 161. 1916.

Peck, F. W., and Boss, Andrew. The cost of milk production. Minn. Agr. Exp. Sta. Bull. 173. 1918.

METHODS OF COLLECTING AND COMPILING STATISTICS

A detailed report of methods used in obtaining the data that have furnished the material for this series of bulletins was given in bulletin 97, issued in 1906, and other reports have given briefly the general plan. The discussion of methods will therefore be brief in this publication.

The work was started in 1902 under the direction of W. M. Hays in coöperation with the Bureau of Statistics, United States Department of Agriculture, and several farmers in the state. Three statistical routes were organized: one at Northfield, Rice County, in the southeastern part of the state; one at Marshall, Lyon County, in the southwestern part; and one at Halstad, Norman County, in the northwestern part. These regions were selected as typical farming communities.

A statistical agent, termed the "route man," was located in each community. He visited daily each farm on the route, obtaining in detail the hours of man and horse labor spent on each operation, a record of expenses and receipts, the amount of farm produce used in the household, the livestock production, feeding records, and all items pertaining to crop and livestock production. Complete inventories of stock and equipment were taken at the beginning and the end of each year to determine depreciation.

In order to determine the cost of man labor by the hour, complete household records were obtained. The cost of board was added to the wages paid and the sum divided by the number of hours worked. The same method was used to determine the cost of horse labor. The crop areas were measured each year to determine the exact acreage of each crop.

In 1904 the number of coöperators in each region was reduced from fifteen to eight in order to include a detailed study of the livestock practices.

In 1911 the Bureau of Statistics, United States Department of Agriculture, withdrew from the project, thereby necessitating, for financial reasons, the dropping of the Marshall (Lyon County) route. The investigations at Northfield (Rice County) and Halstad (Norman County) were continued by the Minnesota Agricultural Experiment Station, the farming in these regions being typical of large sections of the state.

The Rice County route was discontinued at the end of 1912 and a new route opened at Cokato, Wright County. The plan was changed somewhat at Cokato and twelve farms were studied in place of eight as at Northfield and Halstad. Each farm was visited every other day instead of every day and most of the milk testing was done by the creamery tester. The feed was weighed and fed by the unit system, that is, the number of baskets, buckets, measures, scoops, sacks, and other containers of feed were recorded by the farmers and the average weight of the measure of feed was then obtained by the route man. The labor hours were obtained largely by interviews with the farmers, with some aid from labor slips kept by the farm operators.

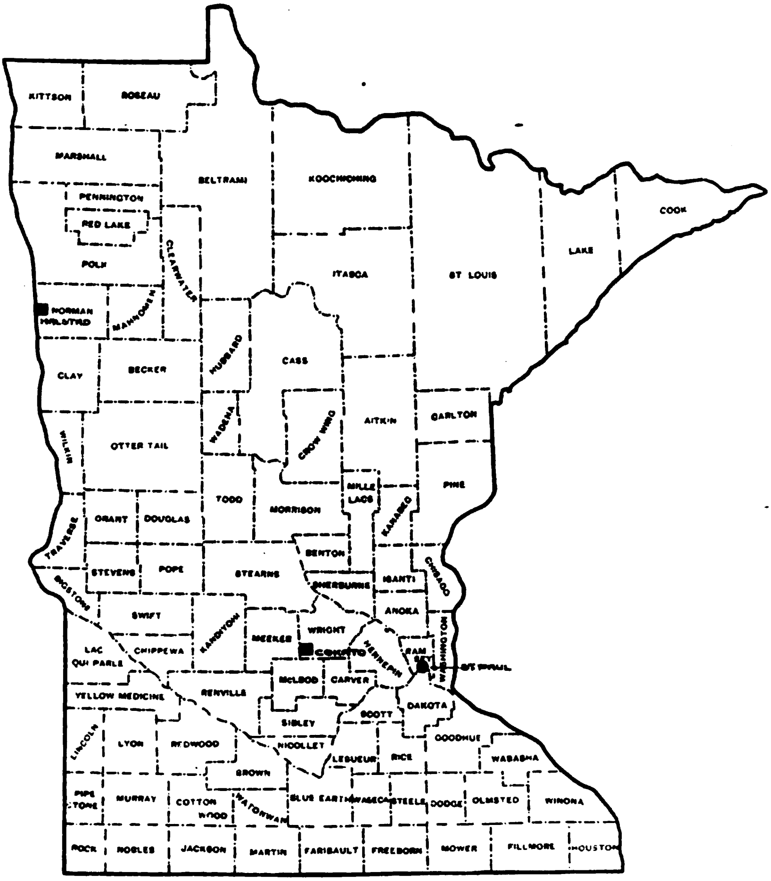

Fig. 1. Location of Statistical Routes
Eight Farms for 5 Years at Halstad
Twelve Farms for 5 Years at Cokato

CLIMATIC CONDITIONS, 1913 TO 1917

The cost of producing crops depends on several factors. One of the important factors in production is the weather. The precipitation and temperature during the growing season influence the yield to a large extent. To understand the conditions under which these cost data were gathered and compiled, a consideration of the climatic conditions is essential.

Table I presents the climatic conditions for the period 1913 to 1917. These conditions are considered typical of the regions studied, for the weather stations are located within forty miles of the statistical farms.

TABLE I
CLIMATIC CONDITIONS, 1913-1917*

Locality	Average annual precipitation		Mean temperature April 1 to Sept. 30		Date of last killing frost in spring	Date of first killing frost in fall	Crop growing days
	Prior to 1913	1913-1917	Prior to 1913	1913-1917			
	Inches	Inches	Degrees	Degrees			
Halstad (Norman Co.)	21.3	19.7	59.4	59.6	May 20	Sept. 20	125
Minneapolis (Hennepin Co.)	29.3	28.8	62.9	61.9	May 10	Sept. 25	135
State average	27.6	26.3	60.0	60.3	....	....	....

---

* **Data are taken from U. S. Weather reports and Minn. Research Bull. 13, "Surface formations and agricultural conditions of Northeastern Minnesota."**

From Table I it will be noted that the average rainfall was less at Halstad and East Minneapolis during the five-year period than the average for the preceding years. The mean temperature was approximately normal for this period as compared with the preceding years. The largest variation was at the East Minneapolis station with a difference of 1 degree. The relation of the temperature and rainfall of these stations to the average for the entire state is also given in the table.

The Cokato district has about ten days more of growing weather than the Halstad region, which is ample to make a great difference in the growing of the corn crop. Comments and notes on conditions within the five-year period follow:

1913—The mean temperature was 1.4 degrees above normal, with the precipitation about normal for the state but 3.8 inches below normal at Halstad and 3.2 inches below normal at Minneapolis. The crop yields of small grain were above the five-year average at Halstad and yields of all crops were above the five-year average at Cokato.

1914—The mean temperature for the year was slightly above normal, but the spring months were cooler and wetter than usual. The average rainfall for the state was 2 inches above normal; at Minneapolis, 1.8 inches above normal; and at Halstad 1 inch above normal. April, June, and August were wetter than normal and the yield of small grain was decreased at Halstad and Cokato as a consequence. The hay crop was above the five-year average.

1915—The mean temperature was slightly above normal, especially during March and April, altho May and June were unseasonably cool. The precipitation was normal at Halstad and 4 inches above normal at Minneapolis. Cokato had one of the best grain crops of the period but at Halstad the yield was only average. Early frosts cut the corn yield considerably below the average for the five-year period.

1916—The mean temperature was 1 degree below normal at Minneapolis and about normal at Halstad, altho the spring months were unseasonably cool. The rainfall was 1.8 inches below normal at Minneapolis and above normal at Halstad. Heavy rains in August with a large amount of rust decreased the yield of small grain at both Halstad and Cokato, the yield of wheat being less than half a normal crop at Halstad and 70 per cent of a normal crop at Cokato. Hay was a good crop in both localities.

1917—The year was unusually cold and dry for the entire state but the distribution of the light rainfall produced a good crop. The temperature was 4 degrees below normal at Minneapolis and 1 degree below normal at Halstad.

The precipitation was much below normal in the Red River Valley but opportune rains in June helped the yield of small grain. The rainfall was 3.6 inches below normal at Minneapolis but yields of small grain were considerably above the five-year average at Cokato. Corn was injured by cold wet weather again and a low yield resulted. The hay crop was generally poor and high prices prevailed.

AVERAGE CROP YIELDS

Table II presents the crop yields per acre for the two localities and compares the average of all farms studied with the average state yields.

TABLE II

CROPS YIELDS 1913-1917 AT HALSTAD AND COKATO, COMPARED WITH STATE AVERAGE

Crop	Halstad			Cokato			Average yield		Inc. or Dec. compared with state average[†]
	Acres	Total yield	Acre yield	Acres	Total yield	Acre yield	Route farms	State[*]	
		Bu.	Bu.		Bu.	Bu.	Bu.	Bu.	Bu.
Wheat	2,721.76	46,849.7	17.2	1,765.84	31,724.6	17.9	17.5	13.7	+3.8
Oats	995.47	38,812.0	39.0	948.43	39,555.0	41.7	40.3	34.4	+5.9
Barley	678.87	41,238.2	24.6	429.15	12,397.8	28.9	25.4	24.7	+0.7
Rye	128.8	3,045.0	23.6	30.84	855.3	27.7	24.4	18.1	+6.3
Flax	......	......	......	45.33	453.5	10.0	10.0	9.3	—0.7
Corn, grain	158.92	4,911.7	30.9	751.44	29,388.7	39.1	37.7	32.3	+5.4
Timothy seed	37.47	120.0	3.2	14.72	73.2	4.9	3.7	......	......
Clover seed	21.84	51.8	2.4	18.63	34.9	1.8	2.1	......	......
Potatoes	422.14	45,157.7	107.0	43.44	9,474.0	218.0	117.3	100.0	+17.3
		Tons	Tons		Tons	Tons	Tons	Tons	Tons
Corn fodder	51.14	156.0	3.0	43.49	107.5	2.5	2.8	......	......
Silage	64.81	326.1	5.0	88.25	615.4	6.9	6.1	......	......
Hay, mixed	1,307.44	1,508.8	1.1	1,259.0	2,661.6	2.1	1.6	1.8	—0.2
Hay, alfalfa	165.31	333.0	2.0	69.74	230.7	3.3	2.4	......	......
Hay, millet	67.77	91.4	1.3	11.39	12.5	1.1	1.3	......	......

[*] U. S. Dept. of Agr. Yearbooks.

[†] A plus sign indicates increase, a minus sign, decrease.

The corn yield at Halstad and Cokato was below normal because of the abnormally small crop in 1915 and a relatively poor crop in 1917. The Cokato district is well known as a good corn-growing community and the conservative average yield of 39 bushels per acre illustrates the effect of averaging the yields over a term of years.

In 1914 the average yield of corn on the farms studied was 47 bushels per acre, but in 1915 it was only 30 bushels. This fluctuation in yield is the general experience with most crops, in most farming districts, over several years.

From a cost standpoint, the yield per acre, within reasonable limits, has little effect on the cost per acre, for a large share of the crop cost is fairly constant regardless of the yield. It is believed that the records from these farms are typical of many other farms, as is well illustrated by a comparison of the yield of these farms and the average. There was an increase on these farms above the state average of approximately 4 bushels of wheat per acre, 6 of oats, 6 of rye, 5 of corn, and 17 of potatoes. The barley and flax yields were approximately the same as the state yield, while a slight decrease is noted in the yield of tame hay. These results indicate that the study was made on fairly typical farms and that the data are representative of many farms in various parts of the state.

AVERAGE FARM PRICES OF FARM CROPS, 1913-1917

The margin between cost per bushel and price per bushel fluctuates widely with different crops and years and even within the year. In terms of the number of bushels required to equal the cost per acre at a current price, this margin between cost and income is entirely dependent on the yield.

In this bulletin no attempt is made to show the margins of profit. One can easily use the average yield as given in Table II with any current price for any year in the period and obtain the acre value of the crop. A comparison with the cost figures will then give an idea of the relative profitableness of the crop.

TABLE III

AVERAGE FARM PRICES PER BUSHEL OR TON OF CROPS IN MINNESOTA, DEC. 1, 1913-1917

Year	Corn	Oats	Barley	Wheat	Flax	Rye	Hay	Potatoes
1913	$0.53	$0.32	$0.48	$0.76	$1.23	$0.48	$6.60	$0.52
1914	0.52	0.40	0.53	1.02	1.28	0.89	6.10	0.32
1915	0.62	0.32	0.49	0.90	1.76	0.81	6.40	0.39
1916	0.80	0.47	0.87	1.62	2.40	1.27	7.00	1.30
1917	1.10	0.63	1.11	2.02	2.95	1.67	12.10	0.91
Average	0.71	0.43	0.70	1.26	1.92	1.02	7.64	0.69
Av. previous 5 years	0.48	0.35	0.59	0.90	1.60	0.63	7.76	0.48
Per cent increase	48	23	19	40	20	62	....	44

Table III and Figure 2 illustrate the fluctuations in farm prices of Minnesota crops and the general upward trend of prices since 1915. Table III shows a comparison of the average prices for 1913-1917 with the average for the preceding five-year period. Hay is the only crop which does not show a decided increase. Rye increased 62 per cent in the five-year period and the other grains and potatoes show large increases.

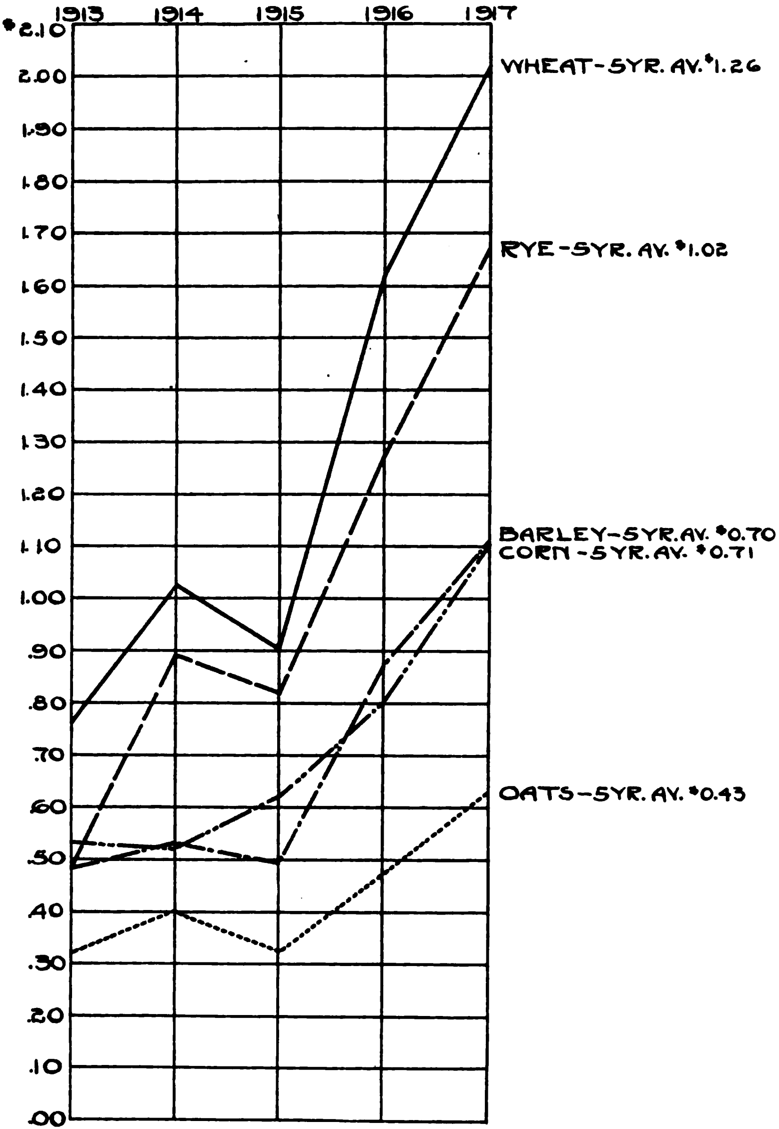

Fig. 2. Price Curves of Five Leading Field Crops, 1913-1917

If the farm prices in 1917 are compared with those of 1912, five years before, the increase shown is 230 per cent for rye, 200 per cent for corn, 170 per cent for wheat and barley, 140 per cent for oats, and 225 per cent for potatoes.

FACTORS OF COST

The factors of cost that enter into the production of field crops are: man labor, horse labor, seed, twine, threshing, values consumed in machinery, land rent, and general expense. In terms of direct and indirect expense, land rent may be considered indirect, and where no rent is actually paid, the farmers usually ignore this item in estimating the cost.

MAN LABOR

Man labor constitutes a large proportion of the cost of crop production.

Under ordinary conditions all labor, both man and horse, constitutes approximately two fifths the cost of producing small grain, one half the cost of producing corn, and from two fifths to one half the cost of producing hay when two crops are cut.

The man and horse labor requirements of crop production are given in detail in Agricultural Experiment Station bulletin 157, and Table IV, taken from that publication, presents the man and horse hours required per acre of crops.

TABLE IV
AVERAGE ANNUAL HOURS OF LABOR PER ACRE REQUIRED IN PRODUCING FIELD CROPS, 1902-1912

Crop	Northfield (Rice County)		Marshall (Lyon County)		Halstad (Norman County)		Glyndon (Clay County)		Average all Farms	
	Hours per acre		Hours per acre		Hours per acre		Hours per acre		Hours per acre	
	Man	Horse	Man	Horse	Man	Horse	Man	Horse	Man	Horse
Wheat, shock-threshed.	14.5	28.0	12.2	29.4	10.8	28.2	......	......	12.3	29.9
Oats, shock-threshed...	14.7	28.2	12.2	30.0	11.7	29.6	......	......	13.5	28.9
Barley, shock-threshed.	14.8	27.9	13.3	31.4	11.9	29.5	......	......	12.8	29.9
Fall rye, shock-threshed	......	......	10.2	27.0	10.4	27.5	......	......	10.3	27.2
Flax, stack-threshed...	15.0	31.0	15.6	40.2	12.9	32.6	......	......	13.7	33.8
Corn, husked.........	30.1	53.6	22.6	51.6	30.9	57.6	......	......	26.2	54.2
Fodder corn, cut, shocked, and stacked	33.7	54.1	25.0	51.0	33.1	52.8	......	......	30.4	52.6
Ensilage.............	33.7	56.0	......	......	31.5	63.5	......	......	32.6	59.8
Potatoes, machine production............	......	......	......	......	......	......	44.4	75.0	44.4	75.0
Mangels*............	......	......	......	......	......	......	180.7	99.3	180.7	99.3
Hay, timothy and clover, first crop....	12.7	11.8	11.0	13.4	12.6	13.8	......	......	12.3	13.0
Hay, timothy and clover, two cuttings..	21.3	20.3	15.6	23.0	......	......	......	......	20.7	21.5
Hay, wild............	9.1	10.0	11.2	13.5	13.5	20.7	......	......	12.2	16.9
Timothy, cut for seed..	......	......	6.0	8.5	4.4	6.1	......	......	5.1	7.1
Clover, cut for seed....	10.1	11.3	8.1	13.6	......	......	......	......	9.2	12.3
Hay, millet...........	18.5	36.3	16.9	39.1	17.3	39.5	......	......	17.3	39.1
Hemp...............	14.3	27.4	......	......	......	......	......	......	14.3	27.4

* Grown at Minnesota Experiment Station.

CASH WAGES

The monthly wage paid greatly influences the cost of crop production. In Minnesota most of the month labor is employed by the season or year. It is becoming a common practice to pay a graduated scale of wages to meet the demands of two seasons: (1) the active crop season from April to November inclusive and (2) the winter, or inactive crop season, from December to March inclusive. On many livestock farms most of the labor is fairly well distributed throughout the year and labor is hired on that basis.

Table V shows the average monthly cash wages by years from 1913 to 1917. The variation between 1916 and 1917 at Cokato is due to local conditions. Several of the coöperating farmers were able to get along with younger help and did not pay the wages that would have been demanded by experienced men. It is noted that the wages at Halstad are consistently higher than at Cokato, especially during the winter months.

FARM BOARD

The cost of board is an important item in the cost of man labor. The monthly cost of board is obtained by determining the total cost of maintaining the farm family and dividing this amount by the number of adults or adult equivalents boarded. Farm help is scaled to the adult as a unit according to age, size, and character of work done.

The cost of board includes groceries, meats, farm produce used, fuel, depreciation on kitchen and room equipment, and current wages for woman labor. The woman wage varied from $3 to $5 per week. Work performed by men about the house was charged at regular rates. It will be noted from Table VI that board constitutes about one third of the total cost of man labor.

TABLE V

AVERAGE MONTHLY CASH WAGES PAID TO FARM LABORERS, 1913-1917

	Halstad					Cokato				
	1913	1914	1915	1916	1917	1913–14	1914–15	1915–16	1916–17	1917–18
January....	$30.13	$27.91	$26.35	$27.14	$34.90	$17.50	$10.00	$26.66	$25.00	$15.00
February...	27.88	27.91	26.35	33.96	30.56	17.50	10.00	26.66	25.00	20.00
March.....	28.42	29.68	29.89	33.96	30.56	18.66	10.00	17.50	22.25	20.00
April......	35.06	34.73	35.41	35.57	36.20	25.00[*]	23.20	20.62	20.00	25.00
May.......	35.06	35.48	35.41	34.90	36.20	25.75	26.58	23.33	24.25	27.00
June.......	34.79	34.50	35.41	35.57	36.20	22.16	25.25	23.33	25.00	25.25
July.......	35.53	36.40	36.67	35.57	36.20	23.33	25.16	32.50	35.00	26.25
August....	36.61	36.40	36.67	34.90	36.20	31.25	26.20	30.00	35.00	28.75
September..	36.96	36.40	35.41	34.90	35.96	27.50	26.75	33.33	34.00	27.50
October....	35.54	36.20	35.41	35.57	35.60	28.75	25.66	35.00	32.50	25.00
November..	33.73	35.09	35.41	34.90	33.96	24.39	22.50	26.66	24.00	22.50
December..	31.75	28.12	31.76	34.90	29.45	19.50	10.00	26.66	30.00	25.00
Average..	$34.47	$34.07	$34.09	$34.75	$34.37	$23.33	$21.37	$26.32	$27.49	$25.50

[*] The statistical period began April 1, 1913, and ended March 31, 1918. The figures for Cokato for January, February, and March are for the calendar years 1914-15-16-17 and 18. They are used in the table, as they are, to facilitate the tabulation.

TABLE VI

COST OF FARM BOARD PER MAN, BY MONTH AND DAY, 1913-1917

Year	Halstad		Cokato	
	Month	Day	Month	Day
1913	$14.01	$0.47	$16.83	$0.56
1914	14.37	0.48	15.30	0.51
1915	13.37	0.45	14.82	0.49
1916	15.03	0.50	15.92	0.53
1917	18.03	0.60	17.21	0.57
Average	$14.96	$0.50	$16.02	$0.53

Average all farms, per month, $15.49; per day, 52 cents.

RATE PER HOUR FOR MONTH LABOR

The wage rates per hour as given in Table VII are based on cash wages and farm board as presented in Tables V and VI. The rate is determined by dividing the total cost of labor on all farms in each region by the total number of hours worked each month by month help. The labor of the proprietor and unpaid family labor are converted into a cash cost at regular hired men's rates so as to include all labor in the cost of production.

Boy labor is scaled according to the work performed, and reduced to a man basis at regular rates. Many operations are performed by boys whose labor on those operations is equivalent to a man's labor. In other instances the boy's labor must be estimated as so many tenths of a man's labor according to the best judgment of the investigator.

The average rate per hour for all farms increased considerably over the rate for the previous five-year period, as shown in the last two columns in Table VII.

The average rate per hour for the year, for all farms, was 15.6 cents, an increase of 14 per cent over the average rate for the period 1908-1912. On the farms studied, the rate for the month labor in 1917 averaged 17.1 cents per hour, which is considerably higher than the five-year average.

RATE PER HOUR FOR DAY LABOR

Table VIII presents the rates per hour for labor hired by the day. The cash wages and the value of board have been divided by the number of hours of labor performed. These rates apply mostly to extra help hired for haying, harvesting, threshing, and silo filling during July, August, September, and October. At other seasons, day help is often employed for building operations, tiling, plowing, and hauling manure.

TABLE VII

RATE OF WAGES PER HOUR (INCLUDING COST OF BOARD) FOR MAN LABOR HIRED BY THE MONTH (AVERAGE OF ALL FARMS COMPARED WITH PREVIOUS FIVE-YEAR PERIOD)

MONTH	Halstad						Cokato						Average all farms	Increase over previous 5-year period
	1913	1914	1915	1916	1917	Average	1913-14	1914-15	1915-16	1916-17	1917-18	Average		
	Cents	Cents	Cents	Cents	Cents	Cents	Cents	Cents	Cents	Cents	Cents	Cents	Cents	Per cent
January	16.51	14.37	16.36	16.41	16.89	16.11	12.61	12.46	15.07	20.21	17.44	15.56	15.83	26
February	16.87	15.25	16.77	16.83	16.87	16.52	12.61	10.96	15.07	20.21	17.00	15.17	15.84	19
March	16.22	13.96	15.64	16.41	15.07	15.46	12.03	8.91	13.00	16.42	17.00	13.47	14.47	10
April	15.13	16.13	16.07	17.23	16.63	16.24	13.03*	13.38	11.58	15.00	17.65	14.13	15.18	10
May	14.28	15.33	15.16	15.16	15.72	15.13	13.81	14.94	15.48	13.80	17.71	15.15	15.14	10
June	15.38	15.62	15.60	14.49	16.28	15.47	13.29	15.90	14.33	16.30	16.95	15.35	15.41	13
July	15.97	15.49	15.05	14.71	16.74	15.59	14.19	15.61	16.13	17.38	21.20	16.90	16.25	21
August	15.32	16.08	15.03	13.75	14.17	14.87	14.52	15.20	14.90	17.57	17.06	15.85	15.36	10
September	15.48	15.29	14.56	14.82	16.74	15.38	13.25	15.93	17.13	16.88	21.01	16.84	16.11	12
October	15.40	15.35	13.43	13.78	15.84	14.76	13.59	14.14	17.16	19.01	16.21	16.02	15.39	7
November	15.25	16.57	18.42	14.88	20.18	17.06	13.35	13.67	15.07	15.49	16.77	14.87	15.97	8
December	16.33	17.76	16.41	16.89	20.42	17.56	12.21	13.84	15.07	19.75	16.44	15.46	16.51	24
Average	15.43	15.52	15.49	15.11	16.61	15.62	13.16	13.78	14.55	16.52	17.97	14.67	15.30	14

* Beginning of statistical year 1913, see footnote, Table V.

TABLE VIII

Rate of Wages per Hour (Including Cost of Board) for Man Labor by the Day, 1913-1917

MONTH	Halstad						Cokato						Average all farms
	1913	1914	1915	1916	1917	Average	1913–14	1914–15	1915–16	1916–17	1917–18	Average	
	Cents	Cents	Cents	Cents	Cents	Cents	Cents	Cents	Cents	Cents	Cents	Cents	Cents
January	17.90	21.95	13.46	21.44	18.85	18.80	....	18.83	15.82	14.42	29.39	25.62	23.58
February	16.94	22.47	13.85	18.08	16.33	18.04	....	13.96	21.15	18.84	19.27	18.40	18.17
March	17.56	22.25	15.14	17.90	15.50	17.92	22.26	13.45	....	13.97	20.34	17.45	17.76
April	20.76	20.00	15.59	11.00	19.07	16.39	18.65*	33.05	18.32	21.87	16.46	18.64	16.92
May	16.26	17.83	17.66	14.25	17.48	16.51	18.37	24.02	17.60	12.29	16.92	18.28	16.80
June	15.15	18.77	16.30	20.28	18.73	18.21	16.66	22.02	....	18.27	25.51	22.57	19.13
July	19.04	20.53	17.18	24.11	17.05	20.05	17.94	18.89	14.85	24.15	28.88	23.07	20.75
August	27.71	26.09	25.05	28.37	28.33	27.26	18.77	25.01	20.77	28.39	27.68	23.97	26.56
September	27.16	27.05	25.13	24.36	26.22	25.84	23.04	17.32	17.05	18.88	30.42	19.63	23.73
October	18.57	22.81	27.23	25.21	25.88	24.72	22.41	24.92	15.14	28.25	31.24	23.62	24.37
November	17.29	18.84	14.87	17.62	17.34	17.00	19.57	21.05	23.64	18.91	31.42	23.74	20.24
December	18.91	12.85	19.41	20.70	23.20	17.86	18.49	13.77	15.95	11.44	32.27	24.54	22.58
Average	21.26	22.58	20.38	22.87	22.23	21.92	20.33	20.44	17.86	19.75	27.40	22.17	22.00

* See footnote, Table V.

TABLE IX

Average Annual Cost of Maintaining a Farm Work Horse

	Halstad						Cokato					
	1913	1914	1915	1916	1917	Average	1913	1914	1915	1916	1917	Average
Interest on investment	$8.19	$8.15	$7.76	$7.95	$8.09	$8.02	$9.73	$8.81	$7.97	$8.27	$7.74	$8.53
Depreciation	1.84	7.83	1.84	5.29	8.04	5.02	15.37	16.57	2.28	15.75	11.90	12.55
Harness charge	2.69	2.83	2.30	1.85	3.17	2.56	2.89	3.47	3.11	2.92	2.88	3.05
Shoeing	0.24	0.07	0.05	0.03	0.04	0.08	0.91	0.60	0.57	0.39	0.62	0.62
Feed	47.84	52.83	59.55	65.25	94.09	64.43	51.59	76.82	77.34	55.77	80.00	67.63
Labor	27.52	27.41	27.45	30.03	38.20	30.22	16.26	18.62	20.86	22.95	24.59	20.59
Misc. expense	0.22	0.32	0.17	0.39	0.22	0.26	0.71	0.27	0.39	0.28	0.30	0.39
Total	$88.64	$99.34	$99.12	$110.79	$151.85	$110.59	$97.46	$125.16	$112.52	$106.33	$128.03	$113.36

HORSE LABOR

The problem of economic and adequate motor power to perform the necessary farm labor confronts every farm operator. As yet horse power rather than mechanical power is used for most of the farm operations. For certain types of work on the larger farms, tractors are being used to good advantage, yet on these farms horses are maintained for certain kinds of work not well adapted to tractor power.

The nature of farm work in relation to seasonal operations is such as to compel the maintenance of work horses during comparatively slack seasons. This means relatively few hours of labor per day through the year and a high cost rate per hour unless economies in maintenance are practiced. In 1917 the annual cost of keeping a work horse on the farms studied was more than $140. This was 15 cents per hour of labor or $3 per day of ten hours during the rush seasons for a team's work. Because of the slack seasons, the daily labor per horse will rarely average more than three and a half hours.

AVERAGE COST OF MAINTAINING A FARM WORK HORSE

The annual cost of keeping a work horse is made up of cost of feed, labor, interest, depreciation, shoeing, harness charge, and miscellaneous expense. The miscellaneous expense is made up of taxes, insurance, and cash cost items. Interest and depreciation have been computed for the work horses from actual annual inventories. The credits for colt increases have been deducted from the depreciation, leaving this figure as the net decrease in value.

On the Halstad farms the depreciation amounted to $5 per horse, while on the Cokato farms it was $12.50, the difference being largely because of fewer colts and older horses on the farms at Cokato.

The figures presented in Table IX on maintenance costs are believed typical of the cost on the majority of Minnesota farms. Knowing the cost of keeping a horse and the number of hours worked, the farm operator can determine the cost per hour and have an idea of the efficiency of his horse labor.

During the previous five-year period, 1908-1912, the average annual cost of keeping a work horse was $94. The average from 1913 to 1917 is $112, an increase of approximately 20 per cent. The increase in 1917 over 1912, 5 years previous, was more than 50 per cent, indicating the heavy increase in cost during 1917.

Table X presents the number of hours worked annually per horse on the farms in the investigation. Because of the more diversified type of farming at Cokato, more horse labor is required than on the farms at Halstad.

Even tho more grain is grown in the latter locality there are fewer days of labor for the horses, owing to the small demand in winter.

TABLE X

Hours of Labor per Horse Annually

	1913	1914	1915	1916	1917	Annual average	Daily average
Halstad.....	987	953	976	905	892	941	3.14
Cokato......	1,024	1,009	993	907	942	974	3.25

Dividing the total maintenance cost by the hours of labor performed gives the cost rate per hour for horse labor. The rate by years and the 5-year average are presented in Table XI. The rate per hour for the period 1908-1912 was approximately 9 cents, giving an increase for the period 1913-1917 of 27 per cent.[2] For 1917 the average rate was 15 cents per hour.

TABLE XI

Cost of Horse Labor per Hour

	1913	1914	1915	1916	1917	Average
	Cents	Cents	Cents	Cents	Cents	Cents
Halstad................	8.98	10.42	10.15	12.24	17.03	11.13
Cokato.................	9.52	12.40	11.33	11.72	13.59	11.63

MACHINERY

FACTORS OF COST IN MACHINERY CHARGES

The use of machinery in crop production entails an annual charge against the crops made up of depreciation, interest, cash repairs, and labor.

Depreciation of farm machinery is usually estimated at 10 per cent per year. This is close enough for general estimating for all classes of machinery. The statistics gathered on a considerable number of farms in Minnesota for the years 1902-1907 showed that the average depreciation of all machines was approximately 7.3 per cent. The records on the same farms for the years 1908-1912 gave 6.7 per cent depreciation. For the period 1913-1917, with some of the same farms and others in Wright County, the records show an average of 7.3 per cent, or the same as for the period 1902-1907. It has been found that the longer records are collected on the same machines, the smaller the depreciation becomes, for they often last much longer than their appearance the first few years would indicate. Having twelve farms out of twenty on record for the first time during the period 1913-1917 a higher average rate of depreciation would result than that shown on older machines.

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[2] Minn. Bull. 145.

Table XII presents the annual depreciation of machines for the two localities and the average for all farms. These computations were made from inventories showing the original value, the years in use, and the present value of each machine. The annual depreciation in dollars thus obtained divided by the average original investment gives the annual rate of depreciation in percentage form.

The inventory value of a machine is based on the number of years used, amount of work done, repairs, shelter provided, present condition, and apparent future usefulness. The auction sale price is also kept in mind in fixing the value.

TABLE XII

ANNUAL DEPRECIATION OF FARM MACHINERY EXPRESSED IN PERCENTAGES

Machine	Halstad	Cokato	Average all machines
	Per cent	Per cent	Per cent
Grain binder	5.76	7.59	6.68
Grain drill	6.24	8.40	7.15
Fanning mill	5.36	10.17	7.55
Smut mill	7.38		7.38
Seed cleaner	6.55		6.55
Wild-oat mill	7.14		7.14
Grain tank	4.96		4.96
Separator	6.78		6.78
Corn grader		10.85	10.85
Corn binder	6.65	9.02	7.8
Corn planter	7.39	8.46	7.93
Corn cultivator	5.58	8.59	6.83
Corn sheller	7.14	10.34	8.77
Hay mower	5.03	9.58	7.49
Hay rake	5.92	7.88	6.8
Hay loader	6.17		6.17
Hay tedder	6.49	6.83	6.64
Hay stacker		10.36	10.36
Forks, ropes, etc	5.2	5.16	5.18
Stack covers		8.42	8.42
Gang plow	5.61	8.94	7.21
Sulky plow	6.02	8.74	7.17
Walking plow	7.0	9.16	8.32
Breaking plow	2.75	10.69	6.01
Disk plow	23.41		23.41
Harrow	3.7	8.74	6.14
Disk	5.65	10.81	7.93
Wagon	4.1	7.21	5.58
Sled	4.29	10.32	6.91
Racks	10.0	11.08	10.52
Manure spreader	9.2	11.18	10.25
Silage cutter	5.47	8.33	6.87
Harness, heavy	4.29	8.6	6.65
Cream separator	7.24	7.64	7.44
Gasoline engine	11.78	8.77	10.59
Gasoline tractor	16.52		16.52
Incubator	7.45	6.76	7.06
Weeder	4.35		4.35
Corn husker		8.84	8.84
Grass seeder		3.85	3.85
Potato cutter	11.87		11.87
Potato treater	10.0		10.0
Potato planter	8.75	7.46	8.16
Potato sprayer	8.67	5.35	7.08
Potato digger	8.03	5.5	6.81
Potato sorter	6.21		6.21

VALUE OF FARM MACHINERY CONSUMED PER ACRE

In order to charge the machinery values consumed in producing crops, it is necessary to determine the acre cost of each machine and distribute it to the various crops. The sum of the cost items for each machine divided by the number of acres on which the machine is used gives the value consumed per acre per year. Table XIII presents these values and shows the percentage of increase in cost per acre over the previous five-year period, 1908-1912.

The average increase in cost for the machines as given in Table XIII is approximately sixty per cent, owing largely to increased cost of labor, higher priced repairs, and larger initial costs of machines.

TABLE XIII

VALUES OF FARM MACHINERY CONSUMED PER ACRE ANNUALLY, 1913-1917

Machinery	Halstad	Cokato	Average all farms	Percentage increase in cost over 1908-1912*
Grain machinery				
Binders	$0.199	$0.312	$0.239	42
Drills	0.136	0.19	0.155	100
Fanning mills	0.032	0.048	0.039	175
Smut mill	0.019	....	0.019	....
Tanks	0.012	....	0.012	60
Wagons, sleds, racks	0.095	0.127	0.106	37
Corn machinery				
Binders	0.361	0.656	0.497	−17
Planters	0.141	0.232	0.181	118
Cultivators	0.258	0.309	0.281	26
Huskers	....	1.709	1.709	....
Wagons, sleds, racks	0.156	0.30	0.231	18
Silage cutter	0.977	1.738	1.237	17
Hay machinery				
Mowers	0.209	0.284	0.247	48
Rakes	0.108	0.164	0.136	72
Stackers	....	0.234	0.234	....
Tedders	0.068	0.10	0.092	48
Loaders	0.119	....	0.119	25
Forks, slings, etc	0.079	0.087	0.082	80
Wagons, sleds, racks	0.189	0.279	0.234	51
Potato machinery				
Cutters	0.06	....	0.06	....
Planters	0.514	0.654	0.537	....
Sprayers	0.364	0.447	0.376	....
Diggers	0.674	0.866	0.781	....
Cultivator	0.258	0.309	0.281	....
Wagons, sleds, racks	0.19	0.784	0.277	....
All crops				
Plows	0.127	0.196	0.152	60
Harrows	0.019	0.045	0.029	52
Disks	0.073	0.109	0.085	124
Manure spreaders	1.149	0.916	1.011	....

* Average increase of machinery cost per acre, 1913-1917 over 1908-1912, 60 per cent.

Table XIV gives the acre cost for the various crops for all machinery used in their production. These costs are used in the tables giving the total cost per acre of the various crops.

TABLE XIV

MACHINERY COST PER ACRE FOR VARIOUS CROPS, 1912-1917

Crops	Halstad	Cokato	Average all farms
Wheat	$1.09	$1.57	$1.26
Oats	1.09	1.57	1.26
Barley	1.09	1.57	1.26
Rye	1.09	1.57	1.26
Corn	1.53	2.20	1.90
Corn silage	2.71	3.80	3.09
Potatoes	2.43	3.15	2.51
Tame hay	1.31	1.61	1.46
Millet	1.36	....	1.36
Timothy seed	0.69	1.48	1.01
Clover seed	....	1.32	1.32
Alfalfa seed	1.17	....	1.17

SEED

The cost of seed has been charged in all cost tables on the basis of actual cash cost or its equivalent. The farmers' home-grown seeds were valued at current prices according to the judgment of the route man.

Table XV shows the amount and value of the seed used per acre in the two localities.

TABLE XV
Amount and Cost of Seed per Acre, 1913-1917

Crop	Halstad		Cokato	
	Amount	Cost	Amount	Cost
	Bu.		Bu.	
Wheat	1.46	$1.80	1.37	$1.98
Oats	2.8	1.23	2.51	1.27
Barley	1.96	1.18	1.94	1.34
Rye	1.62	1.03	1.24	1.04
Flax	....	....	0.51	0.84
Corn	0.18	0.46	0.16	0.47
Corn fodder	0.36	0.89	0.22	0.83
Potatoes	12.1	11.6	....	....

TWINE

Table XVI shows the amount and cash cost of the twine used per acre for the various crops at Halstad and Cokato. The average price of Minnesota Prison twine to the Minnesota farmers for the period 1913-1917 was approximately 12 cents per pound. For the season of 1918 this cost increased fully 100 per cent.

TABLE XVI
Amount and Cost of Twine per Acre, 1913-1917

Crop	Halstad		Cokato	
	Amount	Cost	Amount	Cost
	Lbs.	Cents	Lbs.	Cents
Wheat	2.14	23	2.05	24
Oats	2.21	24	2.52	30
Barley	2.16	24	2.34	28
Rye	2.06	23	2.08	29
Flax	....	....	2.0	21
Corn	2.25	25	2.82	34
Corn fodder	3.95	48	3.1	38

CASH THRESHING

The cash threshing cost per bushel was about three cents for oats and five cents for wheat during this five-year period. This allows only for the common machine crew and spike pitchers furnished by the threshermen. Table XVII gives the average cash cost per bushel.

TABLE XVII
Cash Cost of Threshing per Bushel

	Wheat	Oats	Barley	Rye	Flax
	Cents	Cents	Cents	Cents	Cents
Halstad	4.5-5	3	3	4	....
Cokato	5-6	3.5	4	4.5-5	12-15

LAND RENTAL

Land rent as a cost factor in production of crops is usually ignored by most farmers in their calculations of cost unless they actually pay cash or share rent. The position is taken in this bulletin that it is a proper charge against the crop whether it is paid or not. Land rent is really interest on the value of the land, and in the crop cost tables it has been computed at 6 per cent on $70 land at Halstad and 5 per cent on $100 land at Cokato. The argument that a lower rate of interest than is used here, on such good security as land, is more satisfactory than interest on other securities, is not sound, for all records indicate that farming as a business is subject to great risk and deserves a fair rate of interest on a fair valuation.

Under ordinary conditions, land rental amounts to approximately one third of the cost of producing small grain, one fourth of the cost of growing corn, and two fifths of the cost of growing hay.

GENERAL EXPENSE

One of the difficult phases of cost accounting is the proper distribution of the general expense to the various enterprises comprising the farm business. The principal items of general expense are taxes, insurance, and labor which is not properly chargeable to any one crop or productive enterprise. In this study the charge was found to vary from 54 cents per acre on rye to $1.55 on potatoes. The general expense was distributed on the basis of "operating expense" on these crops. This seems to be the proper basis, for operating and general expense are similar in origin, that is, all expense is similar in that it is produced by the use of labor and capital. The principal factor affecting the general expense charge per acre is that of taxes on the land, which in turn depends largely on the location of the farm in relation to town limits, school districts, and similar factors.

PLOWING

Table XVIII presents the total acreage plowed in spring and fall and the hours and cost per acre in each locality. Tractors were used as power for plowing on too small an acreage to present in table form. Tractor plowing is probably little cheaper than horse plowing altho on large farms the tractor may be an economic investment in the entire year's operations.

At Cokato there is little gang plowing, as is shown by the ratio between man and horse hours and the larger number of hours required per acre for that locality. Obviously there is a saving in man labor by using machinery of larger capacity.

TABLE XVIII
COST OF PLOWING, 1913-1917

Locality	Spring plowing				Fall plowing			
	Total acres five years	Hours per acre		Labor cost per acre	Total acres five years	Hours per acre		Labor cost per acre
		Man	Horse			Man	Horse	
Halstad...........	823.7	2.64	12.39	$1.91	4,847.1	2.84	14.04	$2.00
Cokato...........	646.3	4.21	10.63	1.92	3,048.0	4.11	12.0	2.07

LABOR COST OF APPLYING MANURE

In the tables on crop costs, only the annual labor cost of applying manure is used. No charge has been made for the use of machinery or the fertilizer value of the manure. This value depends on so many varying factors that no attempt has been made to estimate it for the farms studied. Among these factors are: kind and quality of manure, kind of soil to which applied, condition of soil and crop to which applied, season, amount applied, and the distance hauled. Table XIX shows the hours of man and horse labor required per acre to apply 8 or 9 loads per acre and the labor cost of application. On the year basis, the cost is approximately one fourth the cost of application, as the crop acres were covered once in four years on these farms.

Most of the manure was applied with spreaders of about seventy bushels' capacity.

TABLE XIX
COST OF APPLYING MANURE, 1913-1917

Locality	Period	Acres covered	Hours per acre		Labor cost per acre*	Loads per acre	Distance hauled (rods)	Annual hrs. per acre		Annual cost per acre
			Man	Horse				Man	Horse	
Halstad..	5 years	605	9.03	20.88	$3.93	8	40-180	2.25	5.22	$0.98
Cokato..	5 years	1,003	11.01	17.27	3.73	9	40-160	2.75	4.32	0.93

* Labor distributed over four years.

LOSSES IN SOIL FERTILITY

The loss in soil fertility caused by the production of crops is not here considered a proper charge in the data prepared. Even granting that there may be a consumption of fertility and plant food, no just and equitable financial basis exists for the proper charging of this loss. On the other hand, if a crop such as clover or any legume increases the nitrogen in the soil, the cost should be decreased by the estimated value of the increase. The soil can not be compared with machinery, horse power, or buildings. These depreciate constantly in spite of the best management, whereas the soil is kept up and often enriched through good management.

THE ACRE AS A BASIS

The cost per acre rather than the yield unit, as bushel or ton, is the basis taken for computing the cost tables on the various crops. The yields vary so much that this basis could be used only with long-time records with representative yields. The largest items of the cost of crops remain practically the same regardless of the yield; for instance, there is little difference between the cost per acre of a 10-bushel crop of wheat and a 20-bushel crop. The cost of seed, cost of plowing, dragging, seeding, cutting, machinery values consumed, and land rental, comprise over three fourths of the total cost of either the 10- or 20-bushel crop of wheat. The cost of twine, threshing, shocking, and stacking varies somewhat with the yield, yet the variation is so slight as to make the cost applicable to ordinary yields. Undoubtedly careful preparation of the soil and management of fertility will increase the yield without proportionately increasing the cost. To a certain point of diminishing returns, a given amount of preparation will usually yield an increase of profit.

In these studies the cost of marketing has been included where data were available. Distance from market, size of load, condition and character of roads, and yield are factors vitally affecting this cost. The cost of marketing should not be ignored and can easily be accurately determined by multiplying the hours in any case by the rates of man and horse labor given in Tables VII and XI. Table XLII presents the cost of marketing grain on the farms studied.

In all the following tables the data represent five years' results in each locality.

COST OF PRODUCTION PER ACRE

The cost tables following include seed, man and horse labor by operations, twine, cash threshing, general expense, values consumed in farm machinery, and land rental.

In figures for all grains except rye, the total cost includes stack- rather than shock-threshing because of the relatively larger acreage stacked in Wright County, altho more grain is usually threshed from the shock in Norman County. The reverse is true for rye, as noted in Table XXIII.

Total acreage in the cost tables means the number of acres on which the statistics for various operations were gathered. The acreage varies for the different operations because of climatic conditions, weeds, and crop diseases. A field of oats may be partly cut for hay, partly shocked and stack-threshed, or, in cases of very poor yield, not cut at all. The cost of plowing and manuring is based on the total acres handled. Each crop is charged for plowing according to the season in which the plowing was done.

Notes appended to each table show the number of times various operations such as harrowing, disking, and cultivating were performed. The hours required and cost per acre for shock-threshing are also given at the foot of the grain tables.

SPRING WHEAT

The average yield of wheat in Minnesota for the ten-year period 1908-1917, according to the Yearbooks of the United States Department of Agriculture, was 13.9 bushels, with an average acre value of $15.01. The average yield per acre and the farm value at Halstad for the five-year period, 1913-1917, was 17.2 bushels valued at $21.67 per acre, and at Cokato, 17.9 bushels valued at $21.76 per acre. This value has allowed a fair margin of profit ranging from $4 to $5 per acre on the farms studied.

TABLE XX
COST OF PRODUCING WHEAT—FALL PLOWED

Item	Halstad				Cokato			
	Total acreage, five years	Man hours per acre	Horse hours per acre	Cost per acre	Total acreage, five years	Man hours per acre	Horse hours per acre	Cost per acre
Seed	2,869.27	......	......	$ 1.80	1,729.32	......	......	$1.99
Cleaning seed	2,015.66	0.37	0.01	0.06	1,218.84	0.46	......	0.06
Treating seed	1,055.09	0.14	......	0.02	......	......	......	......
Hauling seed	131.13	0.06	0.11	0.02	......	......	......	......
Manuring	604.89	2.25	5.22	0.98	1,002.81	2.75	4.32	0.93
Plowing	4,847.14	2.84	14.04	2.00	3,048.03	4.11	12.0	2.07
Disking*	626.43	0.87	3.49	0.53	391.52	1.0	3.6	0.55
Harrowing	2,845.13	0.74	2.85	0.44	1,691.74	0.85	2.39	0.40
Seeding	2,869.27	0.63	2.4	0.37	1,744.11	0.83	2.56	0.41
Cutting	2,732.14	0.82	3.01	0.47	1,765.84	1.01	3.41	0.56
Twine	2,732.14	......	......	0.23	1,765.84	......	......	0.24
Shocking	2,732.14	1.13	......	0.25	1,765.84	1.55	......	0.26
Stacking	707.05	2.83	3.0	0.89	1,178.22	3.71	3.88	1.08
Stack-threshing, labor	690.82	1.57	0.96	0.50	1,178.22	0.96	0.9	0.28
Marketing	880.55	0.72	1.38	0.28	584.76	1.74	3.15	0.64
Threshing, cash cost	690.82	......	0.69	0.69	1,178.22	......	......	0.95
Machinery cost	......	......	......	1.09	......	......	......	1.57
Land rental	......	......	......	4.20	......	......	......	5.00
General expense	2,726.3	......	......	0.59	1,751.96	......	......	0.86
Totals	......	13.97	36.47	$15.41	......	18.97	36.21	$17.85
Shock-threshing, labor	1,750.61	2.44	3.9	$0.91	587.62	2.22	3.88	$0.81

* The seedbed at Halstad was harrowed 2.3 times and disked 1.8 times; at Cokato it was harrowed twice and disked 1.4 times.

Cost statistics indicate that many wheat growers operate on the bare margin of cost with no profit, while others receive only the direct charges with no land rental. A yield of less than 12 bushels per acre, even under present prices, does not allow any profit.

The wheat crop in the Northwest will probably always be the large cash crop and plans should be made to increase the yield per acre on the wheat farms. Rotations with potatoes as the cultivated crop have been used in the Red River Valley with marked increases in the yield of wheat.

OATS

The oat crop is one of the most valuable feeding crops. Its value as a horse feed and for supplementary dairy and hog rations is well known. From a direct profit-making standpoint the yield per acre in Minnesota has not averaged enough to make the crop a paying one. However, from a management standpoint, in the operation of the entire farm it is a profitable crop and few farms can afford a cropping system without oats. This grain ranks among the first as a grass-seeding medium where the crop is fed rather than sold as a cash crop. From a cost-of-production viewpoint, 38 bushels per acre were required on the farms studied to cover the cost during the period 1913-1917.

TABLE XXI

Cost of Producing Oats—Fall Plowed

Item	Halstad				Cokato			
	Total acreage, five years	Man hours per acre	Horse hours per acre	Cost per acre	Total acreage, five years	Man hours per acre	Horse hours per acre	Cost per acre
Seed	1,132.24	....	....	$1.23	959.09	....	....	$1.28
Cleaning seed	907.62	0.69	....	0.11	595.77	0.58	....	0.07
Treating seed	23.4	0.17	....	0.03	....	....	....	......
Hauling seed	93.55	0.25	0.56	0.08	....	....	....	......
Manuring	604.89	2.25	5.22	0.98	1,002.81	2.75	4.32	0.93
Plowing	4,847.14	2.84	14.04	2.00	3,048.03	4.11	12.0	2.07
Disking	229.83	0.98	3.94	0.90	231.09	1.07	3.9	0.63
Harrowing*	1,083.21	0.75	2.84	0.46	892.27	0.81	2.19	0.37
Seeding	1,132.24	0.64	2.44	0.39	959.09	0.88	2.62	0.43
Cutting	1,014.04	1.05	3.83	0.62	945.23	1.07	3.36	0.56
Twine	1,014.04	....	....	0.24	945.23	....	....	0.30
Shocking	1,014.04	1.25	....	0.29	945.23	1.59	....	0.26
Stacking	305.64	2.64	2.81	0.87	574.88	3.5	3.65	0.99
Stack-threshing, labor	302.11	1.82	1.06	0.59	574.88	1.3	1.05	0.35
Threshing, cash cost	302.11	....	....	1.16	574.88	....	....	1.58
Machinery cost	....	....	....	1.09	....	....	....	1.57
Land rental	....	....	....	4.20	....	....	....	5.00
General expense	1,016.4	....	....	0.69	941.91	....	....	0.88
Totals	....	15.33	36.74	$15.93	....	17.66	33.09	$17.27
Shock-threshing, labor	562.63	2.89	4.66	$1.07	373.55	2.92	4.84	$1.06

* The seedbed was harrowed 2.6 times and disked 1.7 times at Halstad, and harrowed twice and disked 1.5 times at Cokato.

BARLEY

Barley is usually a more difficult crop to handle than oats and usually requires more labor to handle properly. Barley threshing requires more time than oats threshing; and marketing as a cash crop, especially at Cokato, brings the labor requirement to 20 man hours per acre. Smaller loads hauled to market at Cokato account for the higher cost of marketing at that point than at Halstad where large grain tanks are used.

Barley is grown on both fall and spring plowing but in order to compare with other crops fall plowing has been used as the basis of plowing cost.

TABLE XXII
COST OF PRODUCING BARLEY—FALL PLOWED

Item	Halstad				Cokato			
	Total acreage, five years	Man hours per acre	Horse hours per acre	Cost per acre	Total acreage, five years	Man hours per acre	Horse hours per acre	Cost per acre
Seed	1,702.72			$1.18	429.15			1.34
Cleaning seed	1,184.13	0.59		0.09	255.06	0.85		0.11
Treating seed	54.61	0.06		0.01				
Hauling seed	89.82	0.11	0.22	0.04				
Manuring	604.89	2.25	5.22	0.98	1,002.81	2.75	4.32	0.93
Plowing	4,847.14	2.84	14.04	2.0	3,048.03	4.11	12.0	2.07
Disking	1,204.63	1.09	4.37	0.66	115.82	1.24	4.08	0.65
Harrowing*	1,586.63	0.81	2.96	0.47	416.08	1.01	2.65	0.46
Seeding	1,702.72	0.63	2.42	0.38	429.15	0.96	2.86	0.48
Cutting	1,680.57	0.97	3.51	0.56	428.15	1.11	3.5	0.60
Twine	1,680.57			0.24	428.15			0.29
Shocking	1,680.57	1.19		0.26	428.15	1.52		0.27
Stacking	579.01	2.66	2.86	0.85	279.51	3.51	3.72	1.04
Stack-threshing, labor	579.01	1.53	0.81	0.47	279.51	1.31	1.37	0.40
Marketing	155.92	0.87	1.6	0.36	41.99	2.2	4.24	0.92
Threshing, cash cost	579.01			0.69	279.51			1.12
Machinery cost				1.09				1.57
Land rental				4.20				5.00
General expense	1,686.0			0.66	425.47			1.04
Totals		15.6	38.01	$15.19		20.57	38.74	$18.29
Shock threshing, labor	848.03	2.77	4.42	$1.04	149.64	3.11	5.15	$1.10

* The seedbed was harrowed 2.6 times and disked twice at Halstad, and harrowed twice and disked 1.7 times at Cokato.

RYE

Rye is the only fall grain crop used extensively in Minnesota and it is not grown to any large extent in Wright County. This crop is almost universally shock-threshed.

TABLE XXIII
COST OF PRODUCING RYE—FALL PLOWED

Item	Halstad				Cokato			
	Total acreage, five years	Man hours per acre	Horse hours per acre	Cost per acre	Total acreage, three years	Man hours per acre	Horse hours per acre	Cost per acre
Seed	206.02			$1.03	23.84			$0.95
Cleaning seed	189.07	0.38		0.06	9.64	0.42		0.06
Hauling	26.65	0.15	0.3	0.05				
Manuring	604.89	2.25	5.22	0.98	1,002.81	2.75	4.32	0.93
Plowing	4,847.14	2.84	14.04	2.00	3,048.03	4.11	12.0	2.07
Disking	89.1	1.1	4.25	0.59				
Harrowing*	63.14	0.81	2.74	0.40	14.2	0.78	2.11	0.38
Seeding	206.02	0.83	3.82	0.52	23.84	0.92	2.73	0.44
Cutting	128.8	0.92	3.16	0.49	30.84	1.02	2.53	0.55
Twine	128.8			0.23	30.84			0.29
Shocking	128.8	1.50		0.27	30.84	2.09		0.36
Stacking					30.84	3.6	4.48	1.16
Shock-threshing, labor	78.92	3.69	6.3	1.53				
Stack-threshing, labor					30.84	1.12	1.07	0.32
Marketing	10.72	1.07	1.68	0.34	8.22	0.85	1.7	0.33
Threshing, cash cost	69.21			0.96	30.84			1.19
Machinery cost				1.09				1.57
Land rental				4.20				5.00
General expense	128.76			0.54	23.07			1.06
Totals		15.54	41.51	$15.28		17.66	30.94	$16.66

* The seedbed was harrowed 2.4 times and disked twice at Halstad, and was harrowed twice at Cokato.

CORN

Shock corn.—The practice of feeding bundle-corn is becoming more common every year and the economy in labor of handling and feeding the crop in this form is at once apparent to the cattle- or hog-feeder. Table XXIV presents the cost of producing shock corn hauled in from the field. The saving of labor and the roughage are important items.

TABLE XXIV

COST OF PRODUCING CORN—CUT, SHOCKED, AND HAULED FROM FIELD

Item	Halstad				Cokato			
	Total acreage, five years	Man hours per acre	Horse hours per acre	Cost per acre	Total acreage, five years	Man hours per acre	Horse hours per acre	Cost per acre
Seed	829.76	......	......	$0.46	1,129.15	......	......	$0.47
Shelling seed	361.19	0.24	......	0.04	293.05	0.5	......	0.07
Testing seed	197.49	0.52	......	0.08	187.49	0.56	......	0.07
Grading seed	89.56	0.16	......	0.02	66.89	0.08	......	0.01
Manuring	604.89	2.25	5.22	0.98	1,002.81	2.75	4.32	0.93
Plowing	823.74	2.64	12.39	1.91	646.28	4.21	10.63	1.92
Disking*	671.94	1.2	4.85	0.72	940.58	1.63	5.87	0.92
Harrowing	817.8	1.02	3.68	0.59	1,167.96	1.51	4.0	0.70
Planting	834.02	0.88	1.78	0.34	1,064.83	1.04	1.9	0.38
Cultivating	805.73	4.94	11.35	2.08	1,154.84	7.56	14.39	2.91
Cutting	693.61	1.61	4.44	0.77	703.23	1.84	5.19	0.91
Shocking	399.92	3.09	......	0.67	604.33	3.67	......	0.59
Twine	577.27	......	......	0.24	732.86	......	......	0.34
Picking up ears	162.59	1.2	1.28	0.33	239.93	2.04	2.05	0.58
Hauling	183.81	3.77	5.53	1.17	258.72	3.99	4.72	1.11
Machinery cost	......	......	......	1.53	......	......	......	2.20
Land rental	......	......	......	4.20	......	......	......	5.00
General expense	908.62	......	......	0.91	1,140.71	......	......	1.49
Totals	......	23.52	50.52	$17.04	......	31.38	53.07	$20.60

* For all field corn crops the seedbed was disked twice, harrowed three times, and cultivated 4.3 times at Halstad; and was disked 2.6 times, harrowed 2.8 times, and cultivated 4.3 times at Cokato.

Ear corn husked from standing stalks.—The labor cost of husking the ears from standing stalks has been computed by using the rates per hour for man and horse labor for October and November. Practically all husking in these sections of Minnesota is done by the farmer and his regular monthly help; labor is therefore charged by the month rather than by the bushel or the day. Farther south, in the corn belt, large ears and efficient huskers would probably cheapen the cost somewhat, altho the larger yields would tend to increase it slightly. No value is here given for the pasturing of an acre of cornstalks.

TABLE XXV

COST OF PRODUCING CORN—EARS HUSKED FROM STANDING STALKS

Item	Halstad				Cokato			
	Total acreage, five years	Man hours per acre	Horse hours per acre	Cost per acre	Total acreage, five years	Man hours per acre	Horse hours per acre	Cost per acre
Seed	829.76			$0.46	1,129.15			$0.47
Shelling seed	361.19	0.24		0.04	293.05	0.50		0.07
Testing seed	197.49	0.52		0.08	187.49	0.56		0.07
Grading seed	89.56	0.16		0.02	66.89	0.08		0.01
Manuring	604.89	2.25	5.22	0.98	1,002.81	2.75	4.32	0.93
Plowing	823.74	2.64	12.39	1.91	646.28	4.21	10.63	1.92
Disking	671.94	1.20	4.85	0.72	940.58	1.63	5.87	0.92
Harrowing	817.80	1.02	3.68	0.59	1,167.96	1.51	4.00	0.70
Planting	834.02	0.88	1.78	0.34	1,064.83	1.04	1.90	0.38
Cultivating	805.73	4.94	11.35	2.08	1,154.84	7.56	14.39	2.91
Husking	61.79	12.31	16.15	3.57	258.50	13.6	10.72	3.67
Machinery cost				1.53				2.20
Land rental				4.20				5.00
General expense	908.62			0.91	1,140.71			1.49
Totals		26.16	55.42	$17.43		33.44	51.83	$20.74
Marketing					72.24	5.39	10.13	$2.07

Table XXVI presents the cost of producing shock corn husked from the shocks, at Cokato. This practice is not commonly followed, as the hours of labor are increased, the cost is higher, and less of the fodder is consumed after the ears have been removed.

TABLE XXVI

COST OF PRODUCING CORN—CUT, SHOCKED, AND HUSKED FROM SHOCKS, COKATO

Item	Total acreage 5 years	Man hours per acre	Horse hours per acre	Cost per acre
Seed	1,129.15			$ 0.47
Shelling seed	293.05	0.5		0.07
Testing seed	187.49	0.56		0.07
Grading seed	66.89	0.08		0.01
Manuring	1,002.81	2.75	4.32	0.93
Plowing	646.28	4.21	10.63	1.92
Disking	940.58	1.63	5.87	0.92
Harrowing	1,167.96	1.51	4.0	0.70
Planting	1,064.83	1.04	1.9	0.38
Cultivating	1,154.84	7.56	14.39	2.91
Cutting	703.23	1.84	5.19	0.91
Shocking	604.33	3.67		0.59
Husking (shocks)	225.68	12.79	3.34	2.59
Twine	732.86			0.34
Machinery cost				2.20
Land rental				5.00
General expense	1,140.71			1.49
Totals		38.14	49.64	$21.50

Shredded corn.—The shredding of corn is largely a past practice. The silo has provided the storing place for a feed that surpasses shredded corn, and silage has largely supplanted the corn in shredded form. Labor is increased by the shredding operation and it is doubtful if it is a paying method of caring for the corn crop under present conditions.

TABLE XXVII

COST OF PRODUCING CORN—CUT, SHOCKED, AND SHREDDED, COKATO

Item	*Total acreage 5 years	Man hours per acre	Horse hours per acre	Cost per acre
Seed	1,129.15			$0.47
Shelling seed	293.05	0.5		0.07
Testing seed	187.49	0.56		0.07
Grading seed	66.89	0.08		0.01
Manuring	1,002.81	2.75	4.32	0.93
Plowing	646.28	4.21	10.63	1.92
Disking	940.58	1.63	5.87	0.92
Harrowing	1,167.96	1.51	4.0	0.70
Planting	1,064.83	1.04	1.9	0.38
Cultivating	1,154.84	7.56	14.39	2.91
Cutting	703.23	1.84	5.19	0.91
Shocking	604.33	3.67		0.59
Twine	732.86			0.34
Picking up ears	239.93	2.04	2.05	0.58
Shredding	96.5	9.86	12.92	2.76
Machinery cost				2.20
Land rental				5.00
General expense	1,140.71			1.49
Totals		37.25	61.27	$22.25

Fodder corn.—During the last few years corn has become quite popular as a forage crop because of the high yield per acre and comparatively high feeding value. Professor T. L. Haecker, of this Station, places the feeding value of a ton of field and fodder corn at $6.01, as compared with bran at $20. The crop has no value until it is hauled to the barn or feed lot, which operation costs from $1 to $3 per acre, depending on length of haul, condition of soil, ease of hauling, and other conditions.

TABLE XXVIII

COST OF PRODUCING FODDER CORN PLANTED THICKLY FOR FORAGE—CUT, SHOCKED AND HAULED

Item	Halstad				Cokato			
	Total acreage, four years	Man hours per acre	Horse hours per acre	Cost per acre	Total acreage, three years	Man hours per acre	Horse hours per acre	Cost per acre
Seed	227.21			$0.89	82.67			$0.82
Shelling seed	3.16	0.32		0.04	2.39	0.42		0.06
Manuring	604.89	2.25	5.22	0.98	1,002.81	2.75	4.32	0.93
Plowing	823.74	2.64	12.39	1.91	646.28	4.21	10.63	1.92
Disking*	184.69	1.39	5.57	0.95	16.18	1.42	4.27	0.70
Harrowing	182.5	1.01	3.34	0.64	67.11	1.21	3.49	0.58
Planting	228.51	0.89	2.0	0.40	60.66	0.79	1.58	0.30
Cultivating	208.23	3.63	8.03	1.64	61.13	5.59	10.67	2.15
Cutting	222.7	1.87	5.31	1.02	34.92	1.8	5.41	0.90
Shocking	140.11	4.54		1.02	13.04	2.84		0.48
Hauling in	46.88	4.22	5.82	1.31	27.53	4.45	7.85	1.70
Twine	173.02			0.48	76.74			0.38
Machinery cost				1.53				2.20
Land rental				4.20				5.00
General expense	76.64			0.62	1,140.71			1.49
Totals		22.76	47.68	$17.63		25.48	48.22	$19.61

*The seedbed was disked twice, harrowed 3 times, and cultivated 3 times at Halstad; and disked 1.5 times, harrowed 2.7 times, and cultivated 4.5 times at Cokato.

Silage.—With the growth of the cattle industry, corn silage has become very popular as a feed for dairy cows. The large increase in the number of silos throughout the corn belt testifies that not only is it considered valuable for dairy stock but also for beef cattle and sheep. In intensive farming, where each acre of tillable land is made to produce the maximum of feed in demand for livestock production, silage is especially valuable. In supplementing and in actually replacing green summer pasture it has no equal. The convenience in feeding the corn crop in silage form is an important consideration, for the corn is stored in considerable quantity in a place convenient for handling in any kind of weather. The adaptability of the crop to different kinds of livestock and for various systems of feeding makes it of special value on the diversified stock farm. The large yield per acre, the saving of the entire corn crop, and the palatability of the silage ration are other factors in its popularity.

Silage is not a particularly cheap crop in itself but its effect on the other parts of a ration make it an invaluable feed. At Halstad, with a yield of 5 tons per acre the cost per ton amounted to $4.14. At Cokato the yield was 6.9 tons per acre, produced at a cost of $3.70 per ton. Based on its feeding value, it has been calculated to be worth $2.93 per ton compared to bran at $20 per ton.[8]

TABLE XXIX
COST OF PRODUCING CORN SILAGE

Item	Halstad				Cokato			
	Total acreage, five years	Man hours per acre	Horse hours per acre	Cost per acre	Total acreage, five years	Man hours per acre	Horse hours per acre	Cost per acre
Seed	227.21			$0.89	82.67			$0.82
Shelling seed	3.16	0.32		0.04	2.39	0.42		0.06
Manuring	604.89	2.25	5.22	0.98	1,002.81	2.75	4.32	0.93
Plowing	823.74	2.64	12.39	1.91	646.28	4.21	10.63	1.92
Disking*	184.69	1.39	5,57	0.95	16.18	1.42	4.27	0.70
Harrowing	182.5	1.01	3.34	0.64	67.11	1.21	3.49	0.58
Planting	228.51	0.89	2.0	0.40	60.66	0.79	1.58	0.30
Cultivating	208.23	3.63	8.03	1.64	61.13	5.59	10.67	2.15
Cutting	222.7	1.87	5.31	1.02	34.92	1.8	5.41	0.90
Twine	173.02			0.48	76.74			0.38
Filling silo	64.81	8.29	10.92	4.09	100.17	12.52	14.92	4.19
Coal					33.62			0.98
Rental, power machinery					47.08			1.16
General expense	64.81			0.74	88.25			1.50
Farm machinery and ensilage cutter				2.71				3.80
Land rent				4.20				5.00
Totals		22.29	52.78	$20.69		30.71	55.29	$25.37

* The seedbed was disked twice, harrowed 3.2 times, and cultivated 3 times at Halstad; and disked 1.5 times, harrowed 2.7 times, and cultivated 4.4 times at Cokato.

POTATOES

Potatoes, as a cash crop, are particularly adaptable to northern Minnesota. They are a good substitute for corn in the rotations in that region and the soil seems to be excellent for potato production. On small farms this crop readily and profitably supplements the dairy business in the form of a cash crop marketed during the season when a cash income is especially useful. Table XXX presents the cost at Halstad where machine production of potatoes is becoming the common practice. For one or two acres with more hand labor and small machines the cost will be higher than shown in Table XXX.

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[8] Haecker, T. L. Feeding dairy cows, Minnesota Farmers' Library, Bull. No. 12 (out of print).

TABLE XXX
COST OF PRODUCING POTATOES, HALSTAD

Item	Total acreage 5 years	Man hours per acre	Horse hours per acre	Cost per acre
Seed	442.61			$11.60
Manuring	604.89	2.25	5.22	0.98
Plowing	823.74	2.64	12.39	1.91
Disking*	318.59	1.52	6.12	1.07
Harrowing	442.61	1.33	5.07	0.85
Sorting seed	98.06	1.59		0.28
Cutting	435.45	6.4		1.03
Treating	91.6	0.87		0.13
Hauling seed	29.86	1.01	0.87	0.26
Planting	442.61	2.86	4.97	1.07
Cultivating	442.61	6.73	14.0	2.93
Weeding	96.94	0.62	1.25	0.23
Spraying	441.35	1.04	1.75	0.37
Digging	427.14	3.3	10.22	1.86
Picking up	105.75	5.73		1.20
Picking and hauling	113.94	6.26	6.49	2.07
Sorting	28.11	2.74		0.47
Marketing	289.45	7.19	9.74	2.82
Spray material	348.06			0.69
Picking, cash	231.7			5.37
Machinery cost				2.43
General expense	454.57			1.55
Land rental				4.20
Totals		54.08	78.09	$45.37
Weeding, hand	106.74	3.55		$0.57
Hoeing	58.99	3.83		0.73
Hilling	79.25	1.29	2.44	0.47

* The seedbed was disked 2.5 times, harrowed 3 times, cultivated 4.5 times, and weeded once.

FLAXSEED

Flax is usually sown on sod land, especially on new soil, in which case the cost is greater than that given in Table XXXI. Breaking the new sod and preparing the seedbed increase the cost at least $2 per acre.

Practically no flax was raised on the Halstad farms during the period 1913-1917, altho this locality produced a large acreage in former years.[4] Flax is often threshed from the windrow when the weather is dry and threshing machines are readily available, with a consequent saving of from $1 to $2 per acre in the cost of production. The acreage of the crop handled in this way is too small to be of value in table form.

Binding the flax crop is uncommon because it not only increases the cost of production but often delays threshing on account of the slow drying of the tightly bound bundles. It is very doubtful if the flax crop is important on the older settled farms, because of the deteriorating effect on the soil, and the better yields and higher feeding value of other crops. In new sections, however, the flax as a cash crop is often more valuable than other crops. Table XXXI presents the cost of producing flax at Cokato.

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[4] Minn. Bull. 117 and 145.

TABLE XXXI

Cost of Producing Flax—Fall Plowed, Cokato

Item	Total acreage 2 years	Man hours per acre	Horse hours per acre	Cost per acre
Seed	45.33			$0.84
Cleaning seed	1.96	0.51		0.07
Manuring	1,002.81	2.75	4.32	0.93
Plowing	3,048.03	4.11	12.0	2.07
Disking*	36.86	1.45	5.14	0.76
Dragging	45.33	0.93	2.11	0.36
Seeding	45.33	0.9	2.66	0.41
Cutting	32.05	1.76	5.3	0.81
Shocking	25.53	2.59		0.39
Twine	32.05		5.36	0.21
Stacking	23.52	5.72	1.36	1.46
Stack-threshing labor	23.52	2.45	1.31	0.56
Marketing	28.31	0.65		1.05
Threshing, cash cost	23.52			1.57
Machinery cost				1.57
Land rental				5.00
General expense	45.94			0.93
Totals		23.82	39.56	$18.99

* The seedbed was disked twice and harrowed twice.

HAY

TABLE XXXII

Cost of Producing Hay—Timothy and Clover

Item	Halstad				Cokato			
	Total acreage, five years	Man hours per acre	Horse hours per acre	Cost per acre	Total acreage, four years	Man hours per acre	Horse hours per acre	Cost per acre
				First Crop				
Seed				$0.50				$0.75
Mowing	1,169.5	1.46	2.63	0.54	1,261.04	1.67	3.27	0.69
Raking	1,136.94	0.85	1.62	0.32	1,203.08	0.72	1.4	0.30
Tedding	26.8	0.34	0.67	0.12	179.04	1.0	1.85	0.40
Cocking	378.89	0.86		0.14				
Bunching	17.31	0.29	0.23	0.08	309.81	3.02		0.51
Spreading	90.46	1.47		0.25	84.65	2.19		0.37
Hauling	835.78	4.69	5.11	1.37	626.05	7.3	7.3	2.19
Machinery cost				1.31				1.61
Land rental				4.20				5.00
General Expense	1,169.5			0.77	1,261.04			0.91
Totals		9.96	10.26	$9.60		15.9	13.82	$12.73
Bucking	16.58	2.47	3.38	$0.80				
Stacking	327.26	3.73	3.56	1.11	612.83	6.89	6.5	$2.00
				Second Crop				
Mowing	69.19	1.08	2.15	0.42	451.09	1.34	2.65	0.55
Raking	69.19	0.56	1.11	0.22	430.09	0.8	1.53	0.32
Cocking	61.19	0.78		0.13	57.82	2.05		0.34
Spreading	12.5	0.96		0.20	17.5	1.97		0.30
Hauling	38.96	3.0	3.47	0.96	244.33	3.94	4.1	1.17
General Expense	69.19			0.53	451.09			0.59
Totals		6.38	6.73	$2.46		10.1	8.28	$3.27
Totals, two cuttings		16.34	16.99	$12.06		26.0	22.1	$16.00
Stacking	15.23	4.92	4.33	$1.29	184.95	4.21	4.15	$1.20

Timothy and clover.—The hay crop is the cheapest of all crops to produce and is one of the most valuable in Minnesota. Sowing with a grain crop and cutting twice decreases the cost and increases the total value. The cutting of the second crop for hay adds from $2 to $3 to the cost per acre. The value of the seed was determined as follows: 7 pounds of timothy at 7 cents a pound, and 5 pounds of clover at 20 cents a pound, were seeded per acre, making the acre seed cost $1.49. Allowing for three years of grass at Halstad makes the annual seed cost 50 cents per acre and with two years of grass at Cokato the seed cost per year is 75 cents per acre.

TABLE XXXIII
COST OF PRODUCING ALFALFA HAY*

Item	Halstad				Cokato			
	Total acreage, five years	Man hours per acre	Horse hours per acre	Cost per acre	Total acreage, four years	Man hours per acre	Horse hours per acre	Cost per acre
Seeding cost (previous year ¼, with nurse crop)				$2.09				$2.06
				First Cutting				
Mowing	184.84	1.04	2.08	0.46	70.24	1.58	3.16	0.66
Raking	174.03	0.61	1.19	0.26	69.74	0.76	1.41	0.29
Cocking	128.04	2.59		0.44	74.58	3.75	1.16	0.80
Spreading	14.37	1.78		0.27	26.17	2.39		0.41
Hauling	145.78	2.82	2.8	0.87	60.56	5.33	5.61	1.62
General expense	184.84			0.32	70.24			0.99
Machinery				1.31				1.61
Land rental				4.20				5.00
Totals		8.84	6.07	$8.13		13.81	11.34	$11.38
Stacking	30.70	4.72	3.94	1.36	9.68	2.48	3.31	$0.78
				Second Cutting				
Mowing	160.02	1.13	2.26	0.49	68.08	1.43	2.82	0.61
Raking	133.68	0.66	1.35	0.28	62.57	0.69	1.33	0.28
Cocking	97.98	1.99		0.37				
Spreading	28.18	1.83		0.36	34.46	2.67		0.45
Hauling	97.96	3.00	2.54	0.89	51.9	3.89	3.91	1.16
General expense	160.02			0.28	68.08			0.60
Totals		8.61	6.15	$2.67		8.68	8.06	$3.10
Stacking	51.95	4.48	4.21	1.34	16.18	3.83	6.3	$1.50
				Third Cutting				
Mowing	48.82	1.15	2.27	0.46	47.57	1.52	3.05	0.66
Raking	48.82	0.66	1.31	0.25	47.57	0.76	1.51	0.33
Cocking	31.04	1.6		0.31	17.78	1.74		0.33
Spreading	6.24	1.84		0.37				
Hauling	37.87	3.72	3.46	1.07	41.89	2.2	2.34	0.69
General expense	48.82			0.33	47.57			0.46
Totals		8.97	7.04	$2.79		6.22	6.9	$2.47
Stacking	9.97	4.51	4.41	$1.17	5.68	2.82	2.82	$0.86
Total cost of seeding and 3 cuttings		26.42	19.26	$15.68		28.71	26.3	$19.01

* If Alfalfa is seeded without a nurse crop and no crop is grown on the land the year of seeding, the alfalfa should be charged with preparation of the land and rental for that year.

Alfalfa hay.—The value of alfalfa from a feeding standpoint is well known. It provides a maximum amount of nutriment per acre for the hours of labor required. A yield of three tons has been considered equal to ten tons of good quality corn silage while it costs about two thirds as much to produce. In charging the seed cost in Table XXXIII it has been assumed that the crop will last four years. The average yield on the farms studied was 2 tons per acre at Halstad, giving a cost of $7.80 per ton; and 3.3 tons at Cokato, produced at a cost of $5.80 per ton.

There is usually a wide margin between cost and cash or feeding value of alfalfa. The competition with corn for man and horse labor limits its production, however, in the corn belt.

Millet.—Millet is considered here only as a forage crop altho the cost of production is more nearly that of small grains than of the common grass crops.

The yield is often higher than that of good mixed or clover hay and the cost much higher. It should be used in Minnesota more as a catch crop than as a regular forage crop. No millet was grown at Cokato.

TABLE XXXIV
COST OF PRODUCING MILLET HAY, HALSTAD

	Total acreage 4 years	Man hours per acre	Horse hours per acre	Cost per acre
Seed	63.79			$0.75
Manuring	604.89	2.25	5.22	0.98
Plowing	823.74	2.64	12.39	1.91
Harrowing*	60.99	0.92	3.46	0.58
Disking	17.49	1.54	6.18	0.95
Seeding	63.79	0.68	2.73	0.43
Mowing	60.99	1.41	2.82	0.63
Raking	50.64	0.89	1.78	0.41
Cocking	37.32	2.65		0.59
Hauling	22.56	10.73	10.64	3.43
Machinery cost				1.36
Land rental				4.20
General expense	60.99			1.12
Totals		23.71	45.22	$17.34
Stacking	34.02	4.04	4.03	$1.45

* The seedbed was harrowed 2.5 times and disked 2.6 times.

TABLE XXXV
COST OF PRODUCING WILD HAY, HALSTAD

	Total acreage 3 years	Man hours per acre	Horse hours per acre	Cost per acre
Mowing	127.34	1.41	2.8	$0.60
Raking	127.34	0.7	1.39	0.31
Hauling	90.89	4.47	5.48	1.53
Machinery				1.31
Land rental				4.20
General expense				0.72
Totals		6.58	9.67	$8.67
Stacking	36.45	4.72	4.83	$1.55

Wild hay.—Wild hay is usually grown in low, undrained areas. An appreciable amount of land in such areas causes a loss in farm profits, for tame hay not only yields more but can be included in the rotation, thereby improving the productivity of the soil. The land having all been valued at an average price, the wild-hay land must stand the same rental charge as the improved land. The data on wild hay at Cokato were too indefinite to permit tabulation.

Timothy, cut for seed.—With yields of more than five bushels per acre, timothy seed pays fairly well. The selling price is rarely more than five cents per pound but this price with a good yield allows a good profit.

TABLE XXXVI
COST OF PRODUCING TIMOTHY—CUT FOR SEED, HALSTAD

	Total acreage 4 years	Man hours per acre	Horse hours per acre	Cost per acre
Seed	....	....	....	$0.15
Cutting	37.47	0.91	3.26	0.50
Twine	37.47	....	....	0.12
Shocking	37.47	1.01	....	0.24
Stacking	19.53	0.64	0.72	0.17
Stack threshing labor	19.53	0.51	0.46	0.16
Threshing, cash cost	19.53	....	....	0.54
Cleaning seed	5.21	1.54	....	0.26
Machinery cost	....	....	....	0.69
Land rental	....	....	....	4.20
General expense	37.47	....	....	0.51
Totals	....	4.61	4.44	$7.54
Shock-threshing labor	17.94	3.23	3.57	$0.96

Clover cut for seed.—The second crop of clover, cut for seed, provides a good profit when yields of more than two bushels per acre are obtained. In recent years high prices have encouraged the marketing of clover seed. There is seldom a charge for the preparation or care of the soil during the season, as the seed is usually sown with a grain crop.

TABLE XXXVII
COST OF PRODUCING CLOVER—CUT FOR SEED, HALSTAD

	Total acreage 3 years	Man hours per acre	Horse hours per acre	Cost per acre
Cutting	21.84	1.95	5.78	$0.96
Twine	19.84	....	....	0.26
Shocking	19.84	1.61	....	0.24
Threshing, labor	21.84	4.21	3.02	1.27
Threshing, cash	21.84	....	....	1.31
Cleaning seed	11.84	1.14	....	0.18
Machinery cost	....	....	....	0.69
Land rental	....	....	....	4.20
General expense	21.84	....	....	0.50
Totals	....	8.91	8.72	$9.61

FIELD CROP SUMMARY

Table XXXVIII presents the summary of the cost per acre of the various crops in each locality and the average of all farms.

TABLE XXXVIII
Average Annual Cost per Acre (Including Land Rental) of Field Crops

Crop	Table No.	Halstad	Cokato	Average all farms
Wheat, fall-plowed, stack-threshed	XX	$15.41	$17.85	$16.33
Oats, fall-plowed, stack-threshed	XXI	15.93	17.27	16.54
Barley, fall-plowed, stack-threshed	XXII	15.19	18.29	15.81
Rye, fall-plowed, shock-threshed	XXIII	15.28	....	15.28
Rye, fall-plowed, stack-threshed	XXIII	....	16.66	16.66
Corn, cut, shocked, and hauled from field	XXIV	17.04	20.60	19.03
Corn, husked from standing stalks	XXV	17.43	20.74	19.28
Corn, cut, shocked and husked from shocks	XXVI	....	21.50	21.50
Corn, cut, shocked, and shredded	XXVII	....	22.25	22.25
Fodder-corn, cut, shocked, and hauled	XXVIII	17.63	19.61	18.04
Silage, siloed	XXIX	20.69	25.37	23.53
Potatoes, machine production	XXX	45.37	....	45.37
Flax-seed, stack-threshed	XXXI	....	18.99	18.99
Hay, clover and timothy, first crop	XXXII	9.60	12.73	11.22
Hay, alfalfa, three cuttings	XXXIII	15.68	19.01	16.59
Hay, millet	XXXIV	17.34	....	17.34
Hay, wild	XXXV	8.67	....	8.67
Timothy seed	XXXVI	7.54	....	7.54
Clover seed	XXXVII	9.61	....	9.61

COMPARISON WITH PREVIOUS FIVE-YEAR PERIOD

It is of interest to compare the cost of the two five-year periods, 1908-1912 and 1913-1917. The figures were not collected in the same localities except at Halstad where practically the same farms continued the investigation. It is believed, however, that the increase in cost, which averages about thirty per cent for all crops, is typical of the prevailing trend for the two periods. Labor, seed, land rent, twine, and general expense have all increased during the last five years and the figures shown in Table XXXIX are significant of that increase.

TABLE XXXIX
Cost per Acre of Field Crops, 1913-1917
Compared with Previous Five-Year Period, 1908-1912

Crop	Cost per Acre		Increase per acre over 1908-12	Percentage increase
	1913-1917	1908-1912*		
Wheat, fall-plowed, stack-threshed	$16.33	$11.68	$4.65	40.0
Oats, fall-plowed, stack-threshed	16.54	12.92	3.62	28.0
Barley, fall-plowed, stack-threshed	15.81	12.06	3.75	31.0
Rye, fall-plowed, shock-threshed	15.28	11.73	3.55	30.5
Corn, cut, shocked, and hauled from field	19.03	15.65	3.38	21.5
Corn, husked from standing stalks	19.28	15.42	3.86	25.0
Corn, cut, shocked, and husked from shocks	21.50	18.60	2.90	15.5
Corn, cut, shocked, and shredded	22.25	17.85	4.40	24.5
Fodder corn, cut, shocked and hauled	18.04	15.74	2.30	14.5
Silage, siloed	23.53	20.39	3.14	15.5
Potatoes, machine production	45.37	33.08	12.29	37.0
Hay, clover and timothy, first crop	11.22	7.51	3.71	49.0
Hay, millet	17.34	13.38	3.96	29.5
Hay, wild	8.67	7.30	1.37	18.7
Timothy seed	7.54	6.80	0.74	11.0
Clover seed	9.61	8.35	1.26	15.0

*The 1908-1912 cost has been increased to include manuring cost so as to be comparable with the 1913-1917 cost.

To bring the comparison of cost down to the same farms and to single years, the cost per acre of crops at Halstad for 1912 is compared with the cost for 1917. Table XL shows this comparison, with the increase in percentages of the principal crops.

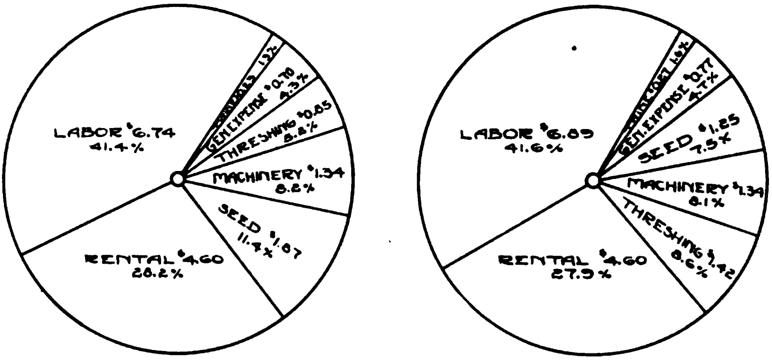
TABLE XL

Comparison of Cost per Acre for 1912 and 1917, Halstad

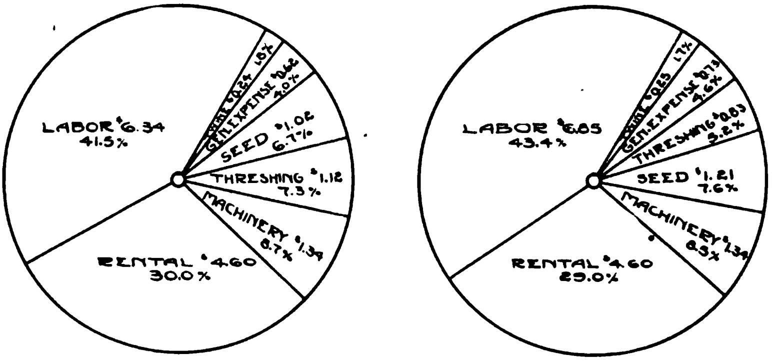
Crop	Cost per acre		Percentage increase 1917 over 1912
	1912	1917	
Wheat, fall-plowed, stack-threshed	$11.59	$17.81	53
Corn, cut, shocked, and hauled	15.22	18.02	18
Corn, husked from standing stalks	15.00	19.62	31
Fodder corn, cut and shocked in field	14.19	17.15	21
Fodder corn, cut, shocked, and hauled	15.85	18.84	19
Silage, siloed	18.92	21.01	11
Oats, fall-plowed, stack-threshed	11.45	17.63	54
Barley, fall-plowed, stack-threshed	13.47	16.66	24
Rye, fall-plowed, stack-threshed	11.17	16.08	44
Hay, clover and timothy, first crop	6.37	9.81	54

The average increase for all crops is approximately thirty per cent, similar to the comparison of the two five-year periods.

The greatest increase is in wheat, oats, and hay. The manuring cost is included in the figures for both years.

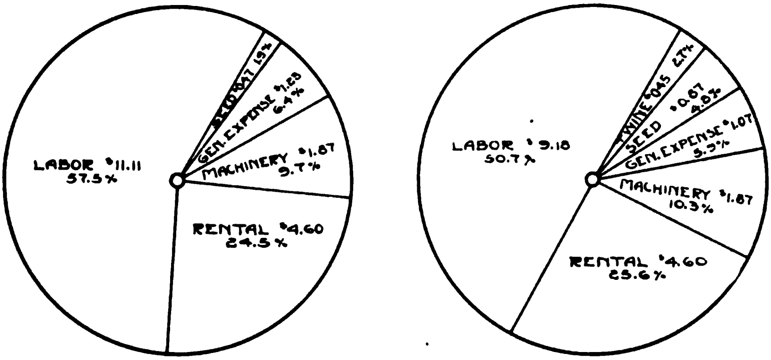


WHEAT OATS



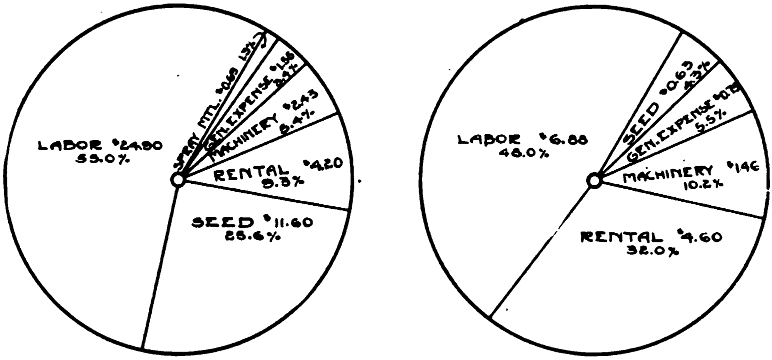
RYE BARLEY

Fig. 3. Distribution of Cost per Acre, in Dollars and Percentages, of Grain Crops, 1913-1917



CORN

CORN FODDER



POTATOES

TAME HAY

Fig. 4. Distribution of Cost per Acre, in Dollars and Percentages, of Field Crops, 1913-1917

YIELD NECESSARY TO COVER COST

TABLE XLI

Yield per Acre Necessary to Cover Cost of Production, 1913-1917

Crop	Average cost per acre	Average farm price Dec. 1, 1913-1917	Required yield per acre to cover cost	Average state yields 1913-1917
		Per bu.	Bu.	Bu.
Wheat, fall-plowed	$16.33	$1.26	13.0	13.7
Oats, fall-plowed	16.54	0.43	38.3	34.4
Barley, fall-plowed	15.81	0.70	21.6	24.7
Rye, shock-threshed	15.28	1.02	15.0	18.1
Flax, stack-threshed	18.99	1.92	9.9	9.3
Corn, husked	19.28	0.71	27.2	32.3
Potatoes, machine production	45.37	0.69	65.6	100.0
		Per Ton	Tons	Tons
Hay, timothy and clover (first cutting)	11.22	7.64	1.4	1.8

Table XLI shows the amount of product necessary to equal the cost of production at the prices indicated. The average cost of production per acre is based on the total acreage and costs at Halstad and

Cokato for the years 1913-1917. Prices are extremely variable while the cost remains fairly constant, therefore a low price would require a larger yield of product and a high price a lower yield than here indicated. The average state yields per acre are also given to show the margin in yield above and below the estimated cost for the same period.

COST OF MARKETING GRAIN

The labor cost of hauling wheat, barley, and corn to market for the years 1913-1917 on the farms studied is presented in Table XLII, and for a haul of from three to four miles amounts to about 2.5 cents a bushel for wheat, 2 cents for barley, and 5.3 cents for corn. For small grain this is about 20 cents per ton mile, while for corn the cost is double this because of the time required to handle it per load and the smaller sized loads.

TABLE XLII

COST OF MARKETING GRAIN PER BUSHEL, 1913-1917

Crop	Bushels	Man hours	Horse hours	Labor cost per bushel	Average distance hauled	Labor cost per ton mile
				Cents	Miles	Cents
Wheat	25,613	1,651	3,057	2.4	4	20
Barley	5,049	228	428	1.9	3	21
Corn	2,825	389	732	5.3	4	47

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AGRICULTURAL EXPERIMENT STATION

EXPERIENCES OF NORTHERN MINNESOTA SETTLERS

BY

F. W. PECK

DIVISION OF AGRONOMY AND FARM MANAGEMENT

UNIVERSITY FARM, ST. PAUL

APR 29 1919
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CONCLUSIONS

FARM MANAGEMENT PROBLEMS

1. From a district-wide standpoint there can be no definite comprehensive organization plans for farm practice in northern Minnesota until a soil survey and land utilization survey (which can be conducted as one) are made.

2. The records of the settlers indicate that small grain crops, potatoes, garden produce, and hay may be made profitable crops in this section. Very few errors are made in choice of crops so far as climatic conditions are concerned, but the marketing facilities are the important limiting factors in crop production, once the land is ready for crops.

3. Clearing the land to make it ready for crops, which also means ready for livestock, to a certain extent, is the largest individual problem a settler has. Unless a constructive program of state aid is worked out, the settlement of many districts will proceed in the same desultory fashion as in the past.

4. The cash returns on the farms studied indicate that livestock, especially dairy stock, is a prime essential to a good income.

5. Receipts from forest products and indicated possibilities in this direction point to the desirability of developing the woods as an annual cash crop.

6. Receipts for labor performed away from the farm are decreasing in amount and importance for the better class of settlers. State aid in land clearing would eliminate largely the necessity for this kind of work.

SETTLEMENT PROBLEMS

1. As mentioned, the first step toward intelligent permanent settlement of this part of the state is a soil and land utilization survey.

2. There is urgent need of a constructive comprehensive program of state aid in land clearing to bring the land into a productive condition.

3. State and county drainage projects are required to drain large areas, under a long-time payment plan. This must be a very definite program, for miscellaneous draining of odd pieces of land with subsequent land subduing practices often constitutes a serious fire menace.

4. Honest, fearless, publicity as to existing conditions and future possibilities of the various sections of this part of the state is absolutely essential. This publicity should disclose the ownership of all

land fit for settlement as agricultural land. One of the bitter complaints of the settlers is the high price of raw land and the pernicious activities of land agents who hold the land for speculation.

5. Some system of issuing real estate licenses under safe regulations should be adopted.

6. Investigations as to cost and methods of clearing land, profitable marketing practices, types of farming, land colonization schemes, and like problems should become a part of the state's program of land reclamation and settlement.

SUMMARY OF STATISTICS COLLECTED

Total number of farms, 141. Counties: Aitkin, Beltrami and Roseau, Carlton, Cass, Hubbard, Itasca, Koochiching, Lake, St. Louis.

Number of farms homesteaded, 76; number of farms purchased, 65.

Average number of acres per farm, 150; average number of acres cleared annually per farm, 3.8; average of total number of acres cleared on each farm up to 1917, 42, ranging from 7 to 250; number of farms settled before 1900, 32; number of farms settled before 1910, 83; number of farms settled after 1910, 26.

Average estimated cost of clearing per acre, $34, for 139 farms, ranging from $10 an acre to $100 an acre.

Average yearly number of acres in crops on 120 farms, 1914 to 1917, 30.

Average estimated value of land per acre on 136 farms, 1914 to 1917, $34, as against the average price paid per acre by those who purchased their land of $9.50.

Average livestock on farms: Horses, 3; cows, 5; other cattle, 8.4; hogs, 8.4; poultry, 44; sheep, 25.

Average amount of working capital at start for 102 of the 141 farmers, $308. No working capital, 39. Average amount of working capital needed to start now, as estimated by 120 farmers, $880.

Average total annual receipts per farm, $936, ranging from $300 to $2,300. Receipts from crops, 24 per cent; from livestock, 42 per cent; from wood products, 23 per cent; from outside work, 11 per cent.

Principal problems of territory emphasized: Poor roads, by 66 settlers; need of markets, by 54; difficulty in clearing land, 39; high rate of interest, 41; poor stock, 17; need of state aid to clear land, 12; high taxes, 14; land speculations, 11; price of wild land, 9; miscellaneous complaints, 39.

EXPERIENCES OF NORTHERN MINNESOTA SETTLERS

By F. W. Peck

PART I

Certain problems confront every agricultural community. Most of the well-settled communities have solved fairly well, at least in a general way, such problems as cropping systems, livestock selection and breeding, seed production and distribution, exchange of help, and rural clubs.

It is in newer country that these problems are most difficult of solution because of the very sparseness of settlement. When there are added to these agricultural problems of production and disposition that must be worked out by trial and experience, such problems as large drainage projects, clearing the land of trees and stones, building substantial roads, and providing better markets, the task assumes enormous proportions.

Northern Minnesota has several inherently difficult problems that affect in large measure the successful and desirable settlement of the land. (1) There is no wide area of a single type of soil—the processes of soil formation in this part of the state, as has been explained by the geologists, were such as to create wide divergence of soil types within very small areas. There is great need for a land survey that will map and define the character of soil types as to adaptability and best utilization. (2) The climate forces the selection of certain crops for production. These crops should be made known to all present and prospective settlers. (3) Most of the land available for settlement at a fair price is cut-over land with but little tree growth. Credit to be obtained by sale of the timber, therefore, is slight. If there is timber, the individual is often unable to market it advantageously. Moreover, the average settler is a man of little means, too often made enthusiastic by rosily painted prospects, with no knowledge of how to attack the problems of a new, undeveloped region. After making a payment for the land he is usually unable to put enough of it into agricultural production to bring a living for his family and to permit him permanently to stay in the region. Many farms have changed hands two, three, and even four times with only 25 or 30 per cent of the possible agricultural land broken for crop production.

Some of the problems are beyond individual solution, for example, the draining of large areas. That becomes a county or state project and requires time, money, and experience for its successful completion.

Widespread and very earnest efforts have been made to bring settlers into this part of the state. The state immigration department is largely concerned with this task. Various development associations, often hastily formed and without knowledge of the practical problems to be solved, have acted as agents in advertising these districts for settlement.

Many inquiries are received by the Agricultural Experiment Station asking for *definite* information as to just what are the real chances of making a home and a respectable living in the cut-over districts. Not only that, but men ask what crops should be grown, what kind of stock maintained, how much it costs to clear the land for the plow, how much cash one should have after making a payment on the land, what the conditions of the roads and markets are, whether one can work out during certain seasons, and many other questions. In short, they want to know the experience of others, for that is the only source of reliable information.

METHOD OF STUDYING THE EXPERIENCE OF SETTLERS

In the spring of 1915, the Division of Agronomy and Farm Management and the Division of Forestry formulated a project whereby the state forest rangers were to act as agents in obtaining data bearing on the problems mentioned, from settlers whom they knew personally and on whose experience, as given, full reliance could be placed.[1] The records obtained covered time and method of settling; the first crops grown; method and cost of clearing and area cleared annually; crops grown at time of record; kind and amount of livestock maintained; sources and amount of annual income; the problems believed most important by the settler and how he believed they should be solved. This personal experience and testimony was the sort of information needed. One hundred and forty-one usable records were tabulated, altho more than two hundred were obtained. The crop seasons covered were those for 1914, 1915, 1916, and a few for 1917. Obviously a very small area was covered in proportion to the large area available for settlement, but the care used in obtaining the data and the general facts used as conclusions made the data applicable to many individuals in the regions studied.

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[1] The author acknowledges with thanks the assistance given by E. G. Cheyney in suggesting the need for such an investigation and in assisting in starting the project, and by D. P. Tierney in advising methods of presentation. Special thanks are due the forest rangers who gathered most of the records and the settlers who coöperated in giving the facts of their experience.

AREAS COVERED IN THE INVESTIGATION

Figure 1 shows the approximate location of the farms from which records were obtained. In Part II is presented a map of each county concerned in this investigation, showing the approximate location of each farm. Accompanying tables give the detailed information by farms, from which the averages have been calculated. Because of the variability in soil types in St. Louis County and because of the widely different conditions within this large county, the data concern two districts which are designated District No. 1 and District No. 2 in the tables.

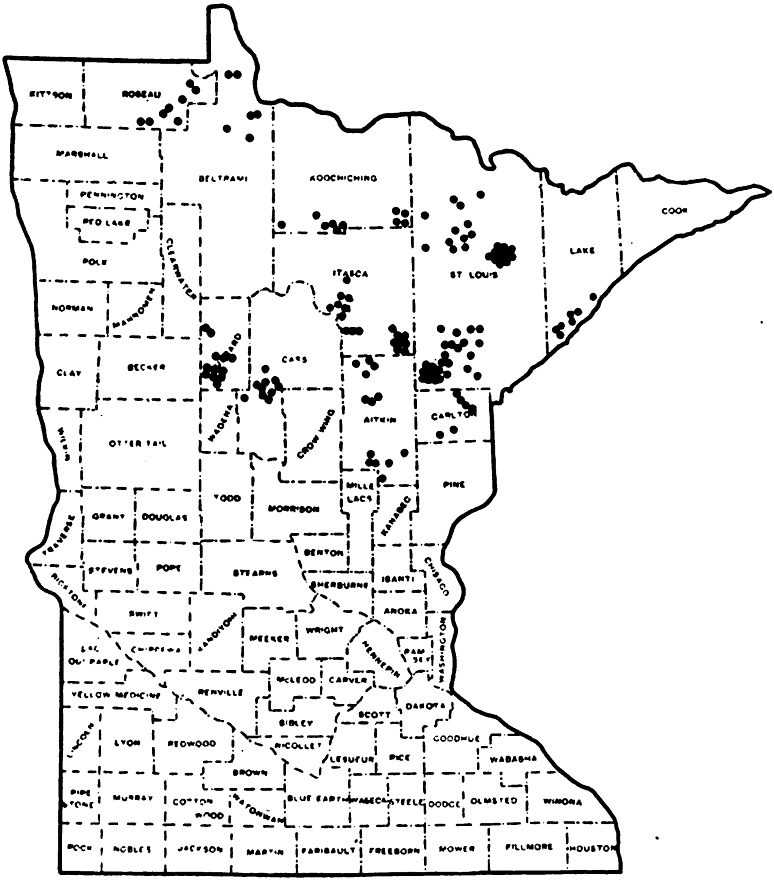

Fig. 1. Approximate Location of Farms on Which Records Were Taken

Table I gives the township and range areas covered in each county so that the portion of the county concerned in these studies can be located quite accurately.

TABLE I
LOCATION OF FARMS FROM WHICH RECORDS WERE TAKEN

County	Number of farms	Townships (inclusive)	Range (inclusive)
Aitkin	13	43 to 52	22 to 26
Beltrami and Roseau	14	158 to 162	31 to 40
Carlton	7	46 to 49	17 to 20
Cass	10	138 to 140	29 to 32
Hubbard	12	139 to 143	32 to 35
Itasca	18	54 to 60	22 to 27 25 to 26
Koochiching	10	63 to 64	22 to 29
Lake	7	53 to 55	8 to 11
St. Louis, District No. 1	24	60 to 65	14 to 21
St. Louis, District No. 2	26	51 to 56	17 to 21
Total	141	....	....

TIME AND MANNER OF SETTLING

Twenty-two per cent of the farms were settled before 1900 and 60 per cent from 1900 to 1910. On the average, in 1916, these farms had been settled about 12 years.

Fifty-four per cent of these farms were homesteaded and the rest were purchased at an average cash cost of $9.50 per acre. The farms for the entire region averaged 150 acres in size. Table II presents these facts for each region and the average for the total number of farms. All averages are weighted averages.

TABLE II
GENERAL FACTS CONCERNING SETTLING ON THE LAND

County	No. farms	No. farms settled			No. farms		Average purchase price per acre	Average No. acres per farm
		Before 1900	1900 to 1910	After 1910	Homesteaded	Purchased		
Aitkin	13	6	4	3	6	7	$10.00	168
Beltrami and Roseau	14	2	8	4	9	5	9.00	214
Carlton	7	2	5	0	1	6	10.50	120
Cass	10	1	5	4	4	6	10.50	210
Hubbard	12	6	5	1	5	7	10.00	196
Itasca	18	2	8	8	4	14	10.50	134
Koochiching	10	1	9	0	10	0	.....	150
Lake	7	2	4	1	3	4	7.00	110
St. Louis, District No. 1	24	3	19	2	23	1	5.00	133
St. Louis, District No. 2	26	7	16	3	11	15	8.25	108
Totals	141	32	83	26	76	65	.....	...
Average	...	..	..	..	..	..	$9.50	150

GETTING STARTED ON THE LAND

It is interesting to note the testimony of the settlers regarding the amount of money they possessed when they started and the amount they deem necessary under present conditions (1914-1917). This sum is in addition to the value of household goods, equipment, and the first payment on the land. The average of the replies to this question showed that 39 of the 141 farmers had no cash after getting on the farms while 102 had about $300 each. The estimate of 120 of these men as to the amount deemed necessary now averaged almost $900, or three times as much as they had.

TABLE III
CASH REQUIRED AND FACTS CONCERNING LAND CLEARING ON 141 FARMS

County	No. of farms	Estimated cash required		No. acres already cleared at start	No. acres cleared annually	No. acres cleared to 1917	Estimated cost of clearing per acre	Range of cost of clearing per acre
		When settled	At present					
Aitkin	13	None (6)[*] $150 (2)	$900 (8)	0	2.7	35	$36.00	$15 to $60
Beltrami and Roseau	14	None	1,200 (9)	15 (1)	6.5	46	20.00	10 to 50
Carlton	7	$625	1,085	2 (3)	4.5	52	44.00	30 to 75
Cass	10	None (4) $210 (4)	1,000 (8)	16 (4)	7.0	66	26.50	15 to 50
Hubbard	12	None (5) $280	780 (11)	71 (5)	7.0	112	15.00	10 to 25
Itasca	18	$650	1,660	0	3.0	23	40.00	20 to 100
Koochiching	10	None (2) $440 (8)	1,000 (6)	0	2.2	25	47.50	25 to 60
Lake	7	None (3) $250	1,300 (3)	0	2.5	22	60.00	40 to 75
St. Louis, District No. 1	24	$30	440	0	2.4	33	60.00	18 to 100
St. Louis, District No. 2	26	$256	510	0	2.5	31	35.00	17 to 65
Average	....	None (39) $308 (102)	880 (120)[*]	....	3.8	42	$34.00	....

[*] Figures in parentheses show the number of farms reporting. In all other instances, all in the locality have reported.

Getting started on cut-over land means clearing the land for crop production as the first step. It will be noted from Table III that very few farms possessed cleared land when settled, and that only an average of 3.8 acres were cleared annually on these farms. The average area cleared each year ranged from 2.2 to 7 acres, depending largely on the type of stumpage and the finances of the settler. The important point is that clearing is a slow process, and this fact should be known before a tract of land is taken. Up to the date of taking these records the average number of acres cleared per farm from the time of settlement ranged from 42 to 112, the latter average being in Hubbard County, which has more prairie land than any other county covered in the investigation.

COST OF CLEARING PER ACRE

The cost of clearing an acre of land and making it ready for the plow is exceedingly variable. It depends on the size, kind, and number of stumps; kind of soil; method of clearing; price of materials and labor used; and other factors. One should have these factors in mind and a general idea of the cost before the work is attempted. The cost per acre to clear for plowing as reported by these farmers, averaged $34. The range of cost in the various localities was from $15 in Hubbard County to $60 in Lake and St. Louis counties (District No. 1). The range within the county was greatest in District No. 1, St. Louis County—from $18 to $100 per acre.

Table III shows the important phases of getting started on the land from a settlement standpoint. Tables VIII, XII, XVI, XX, XXIV, XXVIII, XXXII, XXXVI, XL, and XLIV, in Part II, give the detailed figures on these points for each farm in the respective counties. All the facts for any one farm can be assembled by following the farms by number through the set of four tables for each county group.

CROP STATISTICS

The first cropping on newly settled farms is usually a garden and a patch of potatoes. If there is any wild land on the farm it provides roughage for a team and a cow. The first cash crop is usually potatoes or a little wheat. Practically no reports were received showing crop sales the first year. As only 3.8 acres is cleared annually, on the average, increase of crop sales is very slow. Only 20 per cent of the average farm area had been cleared for crop production up to the time of recording these data. This means an average of 30 crop acres on the 141 farms, with a range of from 15 to 86 acres per farm.

These figures are presented in Table IV. It will be noted that in Hubbard County, with considerable prairie land, the crop area reaches 44 per cent of the total farm area. The average cash crop receipts per farm are also shown in Table IV. The receipts quoted are the average for the years of investigation and represent cash sales only. Potatoes and wheat, with hay in a few instances, were the principal cash crops. A few records showed sales of oats and barley and garden truck. Six farms reported sales of beans in 1916 and 1917. The average cash crop receipts per farm were $225. The range was from $60 in Lake County to $700 in Hubbard County. The maximum crop receipts were $1,875 for a 250-acre farm in Hubbard County in 1917. Wheat and barley were the principal sources of income on this farm. For cropping data for individual farms see Tables IX, XIII, XVII, XXI, XXV, XXIX, XXXIII, XXXVII, XLI, and XLV, in Part II.

TABLE IV
CROP STATISTICS ON 141 FARMS

County	Total No. acres per farm	No. crop acres per farm	Percentage of land in crop 1914-17	Crops grown first two years	Annual cash receipts from crops	
					Average	Range
Aitkin	168	31	18	Potatoes, garden	$226 (12)	$26–$ 847
Beltrami and Roseau	214	56	21	Potatoes, wheat, hay	413	20–1,440
Carlton	120	27	22	Potatoes, wheat, hay	572	0–1,300
Cass	210	35	17	Potatoes, oats, hay, beans.	258	0–1,400
Hubbard	196	86	44	Potatoes, oats, wheat, hay	700	120–1,875
Itasca	134	15	11	Potatoes, garden	165	$0– 660
Koochiching	150	18	12	Potatoes, garden, hay	46 (7)	50– 90
Lake	110	21	19	Potatoes, hay	60	0– 200
St. Louis, District, No. 1	133	18	13	Potatoes, garden	71 (19)	0– 540
St. Louis, District, No. 2	108	24	22	Potatoes, hay, garden	72 (24)	0– 360
Average	150	30	20	....	$225	....

LIVESTOCK STATISTICS

Table V presents the number of each class of livestock reported as being on hand April 1 of the year for which the records were obtained.

For the entire number of farms there was an average of 3 horses, 5 cows, 8.4 head of other cattle, 8.4 hogs, and 44 chickens maintained per farm. But 14 farms reported sheep and on only 11 was the number sufficient to make this class of stock at all important. Only 71 of the farms reported any hogs, while 119 out of 141 maintained cows, the range being from 3.5 cows per farm in Koochiching and Lake counties, to 6 in Carlton, Hubbard, and St. Louis counties.

The dairy cash receipts were by far the most important livestock income, and the cows furnished the principal livestock product for home consumption. The families in this study averaged five persons.

TABLE V

LIVESTOCK STATISTICS ON 141 FARMS

County	Farms	Average number of livestock per farm						Annual cash receipts from stock	
		Horses	Cows	Other cattle	Hogs	Poultry	Sheep	Average	Range
Aitkin	13	4	4.5 (11)[*]	6.0 (11)	6.5 (11)	25 (3)	15 (3)	$325 (12)	$55–$1,365
Beltrami and Roseau	14	4	5.5 (12)	8.0 (8)	9.0 (5)	40 (12)	75 (2)	450	0– 1,190
Carlton	7	3	6.0	5.0 (4)	11.0 (4)	40 (6)	0	600	0– 1,340
Cass	10	3	5.0 (7)	13.0 (6)	15.0 (6)	50 (3)	0	227	0– 770
Hubbard	12	4	6.0 (6)	23.0 (11)	13.0 (10)	60 (11)	26 (5)	973	180– 2,370
Itasca	18	3	5.6 (15)	9.0 (7)	8.0 (13)	57 (13)	0	394	0– 1,095
Koochiching	10	3	3.5 (8)	6.0 (8)	8.0 (4)	40 (6)	12 (1)	344 (7)	72– 1,100
Lake	7	3	3.5	5.5	2.0 (1)	30 (5)	0	236	0– 820
St. Louis, District No. 1	24	2	4.0 (22)	5.0 (16)	6.0 (10)	36 (17)	2 (1)	254 (11)	0– 1,200
St. Louis, District No. 2	26	2	6.0 (23)	6.0 (23)	2.0 (6)	44 (18)	3 (2)	284 (21)	0– 850
Average	....	3	5.0 (119)	8.4 (101)	8.4 (71)	44 (94)	.25 (14)	$393	....

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[*] The figures in parentheses show the number of farms reporting. In all other instances, all in the locality have reported.

In some instances receipts from hogs and sheep increased the total receipts to a very good figure, as will be noted in Table V. The average cash receipts per farm from livestock were $373, being 65 per cent greater than the crop receipts. The range per farm was from $227 in Cass County to $973 in Hubbard County. These figures are only relative. The price and yield per acre each year radically affect crop receipts and also livestock sales. The important point is the relation of the two sums, which illustrates the importance of livestock, especially dairy stock, on these farms. A class of livestock that makes a living possible and also increases the cash receipts is a valuable farm enterprise. Tables X, XIV, XVIII, XXII, XXVI, XXX, XXXIV, XXXVIII, XLII, and XLVI, in Part II, show the detailed livestock statistics for the individual farms.

DIFFICULTY IN MARKETING PRODUCE

One of the common complaints of the settlers in the northern part of the state is that of the lack of ready markets, or of very poor markets for their produce. Hauling cream, potatoes, grain, and vegetables becomes a heavy burden in a country relatively sparsely inhabited, over poor crossroads and with meager shipping facilities. The average distance from the 141 farms to a market for grain, potatoes, or forest products was 9.6 miles. Dairy products in many instances were hauled from 4 to 6 miles to creameries established where sufficient cows are maintained.

The writer visited a prosperous creamery, 19 miles from a railroad, that provided a market for the product of 800 cows within a radius of 6 miles.

The range of distance to a railroad market was from 5 miles for the farms in Carlton County to 17 miles for those in Koochiching County. This is one of the facts that should be known by prospective settlers; especially when a glowing prospectus advertises adequate, well-developed markets.

RECEIPTS FROM FOREST PRODUCTS

The forest products sold on many farms in Northern Minnesota are in reality crop receipts but are kept separate as very often they are not a continuous annual crop but are sold off the land but once. They should, in many instances, be made an annual crop and as such a source of income.

On the farms studied, the cash receipts from forest products amounted to $217 per farm annually, or almost as much as the crop receipts. These products were principally posts and ties with some poles and cordwood. The range in receipts per farm was from none in Lake County to $468 for the farms in District No. 1, St. Louis County.

RECEIPTS FOR OUTSIDE LABOR

Outside labor has in the past provided the living for a great many settlers. In the timber days, logging in the winter and harvest work during the summer provided the cash income. During the last few years outside labor has become relatively scarce. This has undoubtedly had a good effect upon land settlement, for the men have been forced to clear the land and work it into a more productive condition. At the present time the chief kinds of outside work are logging, road building, some harvesting, and day labor in the towns.

The average cash returns per farm for outside labor amounted to $103, or 11 per cent of the total annual receipts. The range of returns from outside labor was from $33 per farm in Beltrami and Roseau counties to $311 per farm in Itasca County. The large receipts for outside work were in Itasca County. Table XXXI, in Part II, shows two instances of large receipts from logging, one of $2,000 and one of $1,200. The greater number of settlers did no outside work and claimed the practice was really a detriment to the development of the country.

TOTAL CASH RECEIVED AND DISTRIBUTION OF RECEIPTS

Table VI shows the average total cash income per farm in each district and the average for the 141 farms. The average is $936 per farm, with a range from $446 in Lake County to $1,833 in Hubbard County. Higher prices for grain during the last few years and a larger crop acreage per farm partly account for the larger incomes in Hubbard County. Within the districts the incomes vary greatly. This shows that the figures are only relative and merely indicative of actual results; any conclusions regarding farm organization and management would not be of value in this brief study with such a small number of farms.

The important feature of Table VI is the relation of each group of receipts to the total and to each other. Crops provided about one fourth of the cash income, livestock products about two fifths, forest products almost one fourth and outside labor about one tenth. These percentages vary in the different districts as shown in Table VI. Tables XI, XV, XIX, XXIII, XXVII, XXXI, XXXV, XLIII, and XLVII, in

Part II, illustrate the variation of individual farms in the different localities as regards sources and amount of income.

TABLE VI

TOTAL RECEIPTS PER FARM AND DISTRIBUTION OF INCOME

County	No. of farms	Total annual receipts per farm		Distribution of receipts			
		Average	Range	Crops	Live-stock	Forest products	Outside labor
				Per cent	Per cent	Per cent	Per cent
Aitkin	13	$ 918	$210–$2,240	25	36	32	7
Beltrami and Roseau	14	976	325– 2,280	42	46	8	4
Carlton	7	1,341	600– 2,640	42	45	2	11
Cass	10	769	175– 1,740	33	30	17	20
Hubbard	12	1,833	600– 3,900	38	53	4	5
Itasca	18	1,081	297– 2,475	15	36	20	29
Koochiching	10	831	314– 1,340	6	47	30	17
Lake	7	446	225– 1,020	13	53	0	34
St. Louis District No. 1	24	721	150– 3,400	10	35	50	5
St. Louis District No. 2	26	738	120– 2,260	10	38	45	7
Average	......	$936	$300–$2,300	24	42	23	11

PRINCIPAL COMPLAINTS OF SETTLERS

It is to be expected that many complaints would be made in a new, undeveloped country. A certain amount of pioneer work is necessary and this usually means hardships, inconveniences, and in many cases actual losses. A record of complaints by reliable experienced settlers may aid in understanding conditions and in approaching a method of aid in the development of the various districts. The complaints have been summarized and are presented in Table VII.

It will be noted that complaints of the roads are largest in number —22 per cent of the 302 complaints tabulated. This is very natural, for every new country must have a relatively long period of road building. Many of the complaints had to do with crossroads and roads from isolated farms to main highways. Obviously it will be some time before this country can afford good roads in all seasons for the majority of the farms.

Poor markets or the lack of markets was the ground for the second largest number of complaints—54 of the 302. This again is expected of sparsely settled regions, for large population centers create markets, and transportation facilities are created by the demands of such centers for necessary food products.

Greater development of the dairy industry in these sections will bring more creameries; the development of the sheep and hog industry will create coöperative marketing associations; and when the products in demand are produced, means for their disposition will follow. This problem should receive the attention of those interested in increased livestock production.

TABLE VII
Principal Complaints of Settlers on 141 Farms

County	No. of farms	Complaints regarding									Total
		Poor roads	Poor market	Slow, costly land clearing	High interest	Poor livestock	Need of state aid in clearing	High taxes	Land speculators	Price of wild land	Mis-cellaneous	
Aitkin	13	3	1	4	2	1	1	......	......	......	2	14
Beltrami and Roseau	14	10	5	6	8	4	......	1	1	......	7	42
Carlton	7	5	1	2	4	2	1	......	1	......	3	19
Cass	10	5	6	3	7	2	1	1	1	......	3	29
Hubbard	12	4	8	6	2	......	1	......	2	......	6	29
Itasca	18	9	7	6	6	......	1	1	......	......	6	36
Koochiching	10	6	4	2	4	1	2	3	1	......	......	23
Lake	7	2	1	1	3	......	1	3	1	......	4	16
St. Louis, District No. 1	24	5	5	3	2	3	1	......	......	2	4	25
St. Louis, District No. 2	26	17	16	6	3	4	3	5	4	7	4	69
Totals	......	66	54	39	41	17	12	14	11	9	39	302
Percentage of total	......	22	18	13	14	5.5	3.5	4.5	3.5	3	13	100

High interest rates and lack of means of obtaining credit were subjects for complaint, altho it is believed that this sentiment voices the abuse of earlier years more than at present. There has not yet been time for the federal farm loan act to become widely operative over this part of the state. Relief for this complaint will surely be available.

One of the greatest problems and one that is constantly before the settlers of these districts is the slowness and difficulty of clearing the land for crop production. Many settlers express their belief in the practicability of some sort of state aid as the solution of this problem. The legislature of 1916 passed an act providing for a revolving fund of $100,000 to be spent in clearing state land before its sale to the settlers. The plan is being worked out and clearings have been made under this act, but conclusions as to its effect on the land-clearing problem would be mere conjectures at this time. This problem is the key to the constructive permanent settlement of these sections of the state. Unless this subject receives study, and a constructive, helpful program of land clearing and utilization is laid out, the northern part of the state will continue its process of a retarded haphazard development.

Among other complaints recorded from the settlers' data are those against land speculators, the high prices for wild land, high taxes, poor quality of livestock, railroad facilities, and difficulty in hiring labor. If one stops to inquire into the reason for conditions that prompt most of the complaints, it is seen at once that most of them are indigenous to a new undeveloped country. Even speculation of the land with its consequent abuses is probably a natural stage in the development of this region. This does not excuse the tolerance of dishonest practice that is known to exist in selling land. Some of the losses incurred by the buyers of land in these districts are due to their lack of common business sense in buying without investigation or intelligent inquiry. Probably the remedy for this evil lies in full publicity of the practice and impartial honest description of the land and its possibilities by the state without regard to the "advertising features" that usually color the word pictures of Northern Minnesota.

SETTLERS' IDEAS OF WHAT SHOULD BE DONE

Each settler was asked what he considered the first steps that should be taken wisely and permanently to settle his section of Northern Minnesota. From the replies to this question the following answers are selected as typical. They are given by counties and districts, and represent in a small way the ideas of settlers who have had considerable experience. Most of them can not have a wide vision of the proper solution of the important problems to be solved, but their testimonies should be recorded as a means of getting an insight into the practical man's view of the important work of developing Northern Minnesota agriculture.

AITKIN COUNTY

1. The land should be pastured with sheep the first few years.
2. A more industrious class of people should be sought through truthful advertising.
3. Lower interest rates for farm improvements should be charged and better facilities for obtaining credit offered.
4. A county agent should be installed to advise with settlers. (A county agent is now located in Aitkin County.)
5. State aid in clearing land and truthful advertising of the actual conditions and possibilities are needed.

BELTRAMI AND ROSEAU COUNTIES

1. The land should be sold at its productive value.
2. A better cash market for products should be created.
3. The state should furnish dynamite to the settlers at cost.
4. The possibilities for dairying should be advertised.
5. Farmers with at least $3,500 cash who know how to farm should be induced to take land.
6. Land speculators who are at present a detriment to the state should be eliminated.
7. By means of easier credit, more livestock, particularly cows and sheep, should be brought in.
8. A county agent should be employed to advise the settlers. (Each of these counties now has a county agent.)
9. Practical methods for building and improving crossroads with state aid should be devised.
10. Taxes should be raised on land held for speculation and roads built with the money.
11. Swamps should be drained by a state drainage project and crossroads built by the same means.
12. State aid for clearing land, to be charged to the settler as the farm is developed, should be the first thing provided.
13. State aid for building roads should be provided and cheaper dynamite for land should be available to the settler.

CARLTON COUNTY

1. The state should work out a method of clearing the first 10 acres and of draining land where it is needed, and construct permanent

roads so the settler can start as a producing man without spending the first ten years trying to get a start.

2. Land speculation should be eliminated and the country truthfully advertised.
3. Better roads should be built.
4. Dynamite should be available at cost.
5. Indians should be allowed to sell their land under proper regulations so that it can be developed.
6. The interest rate should be lowered and government aid obtained for road-building.
7. There should be state aid for borrowing money for improvements and for clearing land so land can be put into crop at once.

CASS COUNTY

1. Speculation in wild land should be eliminated.
2. There should be better roads and easier terms for payment for land by the settler.
3. Workers are needed instead of hunters and fishermen.
4. The tax on personal property should be removed and interest rates should be lowered.
5. State aid is needed in clearing land and easier terms for loans for land-clearing operations should be provided.
6. The large commissions charged by land agents in selling land should be eliminated.
7. The price of wild land to the settler should be reduced.

HUBBARD COUNTY

1. State aid in clearing state lands should be given.
2. More sheep are needed.
3. The rate of interest should be lowered.
4. The federal farm loan act should be developed.
5. A railroad should be built from Detroit to Duluth. It takes two days to go to market and back with teams.
6. Some system of building better crossroads other than leaving the work to the individual settler should be devised.
7. State aid in clearing state land should be provided.
8. Land should be taken from speculators, prices lowered, and terms made easier.
9. Speculation should be controlled. Better schools and roads should be built.

ITASCA COUNTY

1. The county should be bonded to build better roads.
2. State aid in clearing land, free clover and timothy seed, and easier methods of getting more cows should be provided.

3. The state should slash and burn a portion on each 40 acres and seed it down for pasture.
4. Some method of building better roads, especially crossroads, should be provided.
5. Swamp lands should be drained.
6. Farmers with considerable capital and knowledge of farming should be induced to settle here.
7. The tax rate on speculative land should be increased and that on productive land lowered.
8. The state should aid in clearing 10 acres of each quarter section.
9. State aid in draining large areas should be given.
10. Dynamite should be obtainable at cost, and interest rates for loans to settlers lowered.
11. State and federal aid is needed in building a railroad through the country and draining swamps so the land can be cropped.

KOOCHICHING COUNTY

1. Speculators should be eliminated.
2. Taxes should be lower to settlers, and aid in road building given.
3. State aid in road making is needed and land should be ditched only when used.
4. State aid in clearing five acres and building house should be given.
5. Roads should be built and taxes lowered.
6. State aid in clearing and selling land is needed.

LAKE COUNTY

1. Taxes on improvements should be removed.
2. State aid in starting settlers on land should be provided.
3. Taxes on improvements should be removed.
4. Unscrupulous land agents should be eliminated.
5. Coöperative buying should be encouraged and state aid in starting a home provided.

ST. LOUIS COUNTY (DISTRICT NO. 1)

1. Swamps should be drained and better roads built by state aid.
2. Men with more capital and better knowledge of farming are necessary.
3. Livestock loans should be obtainable at a low rate of interest.
4. Advice and financial aid for stocking farms with cows are greatly needed.

ST. LOUIS COUNTY (DISTRICT NO. 2)

1. The state should clear part of the land to start the settler.
2. Lower interest rates and better roads should be provided.

3. Speculation on land by large corporations should be made impossible.
4. Taxes should be lower and land sold at more nearly its value.
5. Better crossroads should be built and taxes lowered.
6. Price of wild land should be reduced.
7. The state should control the price of wild land and speculation should be prohibited.

PART II

Part II contains maps of each county concerned, showing the location of the farms from which records were taken. It also presents the records of the individual farms that make up the averages presented in Part I. Such data may be exceedingly valuable in following specific farms through the various tables, showing the wide variations between farms and the productive factors of each farm.

The widely varying soil, marketing and crop-producing conditions in all the localities studied makes the individual farm record of particular value to those interested in the farm operations and problems of this part of the state. Obviously, any more detailed description of the individual farms and methods of management must be the subject of further investigation.

In all tables, the figures in parentheses indicate the number of farms used in obtaining the averages. In other cases the total number of farms is used. Where essential, the averages are weighted.

AITKIN COUNTY

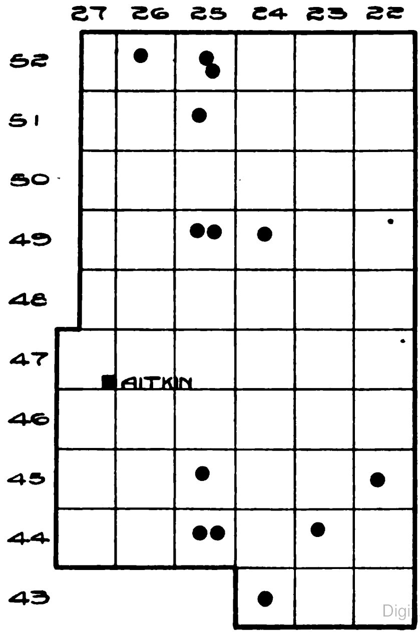

Fig. 2. Location of Coöperating Farms in Aitkin County

TABLE VIII
CASH REQUIRED TO START AND FACTS CONCERNING LAND CLEARING ON 13 FARMS IN AITKIN COUNTY

Farm No.	Year settled	Estimated Cash required		No. acres cleared when farm was taken	Average No. acres cleared annually	Total No. acres cleared to 1917	Estimated cost of clearing per acre
		When settled	At present				
1	1892	$10	$ 300	0	4.5	30	$50
2	1886	None	....	0	4.0	60	50
3	1902	None	500	0	3.0	115	20
4	1913	None	1,000	0	11.0	30	15
5	1911	None	1,000	0	2.0	10	15
6	1908	200	1,000	0	5.0	15	20
7	1889	....	....	0	2.5	30	....
8	1882	None	500	0	1.2	40	20
9	1901	None	....	0	2.0	25	35
10	1909	150	1,000	0	2.5	7	50
11	1893	....	....	0	1.5	12	60
12	1908	600	1,000	15	10.0	130	15
13	1895	....	....	0	2.0	30	51
Average	....	....	$900	0	2.7	35	$36

TABLE IX
CROP STATISTICS ON 13 FARMS IN AITKIN COUNTY

Farm No.	Total acres in farm	No. acres unfit for agriculture	No. acres in crop	Percentage of farm in crop	Annual cash receipts from crops	Crops grown last few years
1	140	0	30.0	21.0	0	Potatoes, carrots, hay
2	280	0	73.0 (70 hay)	26.0	0	Oats, hay
3	205	0	60.0	29.0	$665	Clover seed, peas, oats, potatoes, hay
4	140	0	....	....	65	Wheat, potatoes, buckwheat, onions
5	160	20	95.0 (85 hay)	60.0	110	Potatoes, corn, hay
6	120	0	16.0	13.0	65	Potatoes, corn, hay
7	240	0	21.0	9.0	60	Oats, potatoes, corn, hay
8	120	0	17.0	14.0	399	Potatoes, corn, hay
9	100	20	11.0	11.0	55	Wheat, oats, potatoes, corn
10	120	0	0.5	0.4	26	Beans, peas, potatoes
11	278	0	7.0	2.5	420	Wheat, barley, oats, potatoes
12	214	44	56.0	26.0	....	Clover seed, buckwheat, oats, barley, potatoes
13	160	7	18.0	11.0	847	Oats, peas, hay, truck
Average	168	....	31.0	18.0	$226	....

TABLE X
LIVESTOCK STATISTICS ON 13 FARMS IN AITKIN COUNTY

Farm No.	No. of stock on hand April 1—first year record was taken						Annual cash receipts from stock
	Horses	Cows	Other cattle	Hogs	Poultry	Sheep	
1	3	7	0	1	25	0	$647
2	5	0	40	4	....	0	526
3	10	3	3	25	....	0	360
4	4	....	0	....	....	0	100
5	4	3	1	10	....	0	20
6	3	4	1	0	....	0	150
7	6	5	0	0	....	0	150
8	3	6	7	0	....	5	200
9	2	3	1	0	....	0	55
10	....	....	....	....	....	....	63
11	3	10	0	0	....	20	260
12	2	4	....	8	25	20	....
13	2	9	10	2	25	0	1,365
Average	4	4.5	6	6.5	25 (3)	15 (3)	$325

TABLE XI

Distribution of Income on 13 Farms in Aitkin County

Farm No.	Income from				Total
	Crops	Live-stock	Forest products	Outside labor	
1	0	$647	$625	$6	$1,278
2	0	526	1,100	0	1,626
3	665	360	300	0	1,325
4	65	100	0	200	365
5	110	20	650	150	930
6	65	150	0	0	215
7	60	150	0	0	210
8	399	200	0	0	599
9	55	55	288	0	398
10	26	63	256	465	810
11	420	260	144	0	824
12	....	....	....	....	....
13	847	1,365	130	0	2,342
Average	226	325	303	64	$918
Percentage of total	25	36	32	7	....

BELTRAMI AND ROSEAU COUNTIES

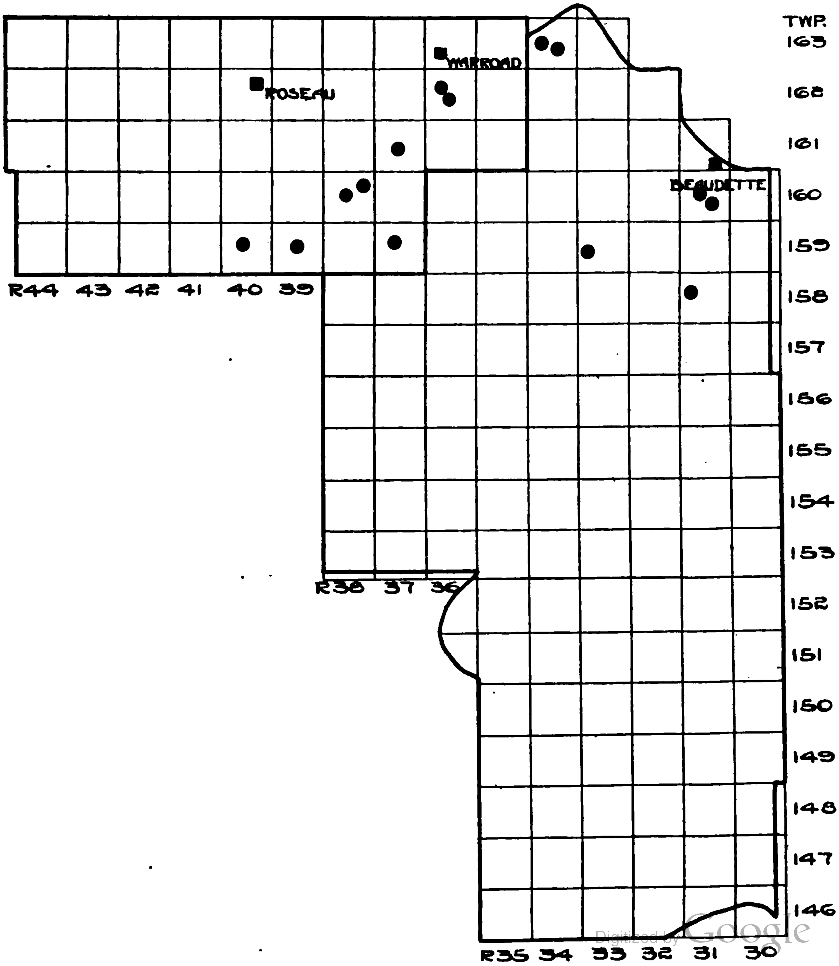

TABLE XII

Cash Required to Start and Facts Concerning Land Clearing on 14 Farms in Beltrami and Roseau Counties

Farm No.	Year settled	Estimated Cash required		No. acres cleared when farm was taken	Average No. acres cleared annually	Total acres cleared to 1917	Estimated cost of clearing per acre
		When settled	At present				
1	1904	$200	$1,500	0	4.0	50	$15
2	1887	None	500	0	4.0	60	10
3	1911	None	1,600	0	2.5	10	35
4	1900	None	1,000	0	8.0	95	....
5	1899	None	700	0	17.0	300	25
6	1908	12	1,000	0	3.5	24	10
7	1905	325	800	0	2.0	42	10
8	1906	60	....	0	1.5	10	25
9	1913	None	2,000	0	10.0	40	50
10	1915	1,800	1,800	0	3.5	10	23
11	1912	....	....	0	5.0	20	25
12	1908	....	....	0	5.0	40	15
13	1908	50	1,000	0	3.5	40	10
14	1909	1,000	2,000	15	16.0	110	10
Average.	....	....	$1,200	15 (1)	6.5	46	$20

TABLE XIII

Crop Statistics on 14 Farms in Beltrami and Roseau Counties

Farm No.	Total acres in farm	No. acres unfit for agriculture	No. acres in crop	Percentage of farm in crop	Annual cash receipts from crops	Crops grown last few years
1	240	0	7.0	3.0	$54	Rye, potatoes
2	200	0	50.0	25.0	184	Potatoes, wheat, oats, barley, rye
3	160	0	....	....	....	
4	160	0	67.0	42.0	1,030	Wheat, oats, barley, hay, potatoes
5	480	0	259.0	54.0	1,440	Wheat, oats, barley, hay, potatoes
6	160	0	14.0	9.0	187	Wheat, oats, barley, potatoes
7	320	0	25.0	9.0	205	Wheat, oats, corn, potatoes
8	156	0	6.5	4.0	20	Potatoes, hay, garden
9	80	0	39.0	49.0	715	Corn, oats, onions, potatoes, hay, rutabagas
10	80	0	2.0	2.5	61	Corn, oats, potatoes, rutabagas
11	160	0	3.0	2.0	200	Potatoes, rutabagas, carrots
12	360	0	35.0	10.0	525	Potatoes, rutabagas, garden
13	160	0	28.0	17.0	300	Oats, barley, potatoes
14	280	0	84.0	30.0	448	Wheat, oats, rye, potatoes, clover
Average.	214	....	56.0	21.0	$413	....

TABLE XIV

Livestock Statistics on 14 Farms in Beltrami and Roseau Counties

Farm No.	No. of stock on hand April 1—first year record was taken						Annual cash receipts from stock
	Horses	Cows	Other cattle	Hogs	Poultry	Sheep	
1	5	5	5	....	30	0	$95
2	2	6	....	1	50	80	285
3	....	....	....	....	....	....	....
4	4	12	....	2	30	0	282
5	11	15	23	11	65	0	780
6	2	3	....	5	50	75	1,190
7	3	7	....	....	75	0	619
8	2	2	1	....	18	0	125
9	5	2	7	....	50	0	490
10	1	1	1	....	4	0	23
11	1	2	....	....	25	0	....
12	1	5	8	....	40	4	147
13	2	5	7	2	....	0	130
14	5	7	14	24	40	1	676
Average.	4	5.5	8 (8)	9 (5)	40	......	$450

TABLE XV

Distribution of Income on 14 Farms in Beltrami and Roseau Counties

Farm No.	Income from				Total
	Crops	Live-stock	Forest products	Outside labor	
1	$54	$95	0	$175	$324
2	184	285	0	0	469
3	....	....	....	....	....
4	1,030	282	0	0	1,312
5	1,440	780	0	160	2,380
6	187	1,190	0	0	1,377
7	205	619	0	0	824
8	20	125	234	....	379
9	715	490	100	100	1,405
10	61	23	0	0	84
11	200	....	....	....	....
12	525	147	708	....	1,380
13	300	130	0	0	430
14	448	676	0	0	1,124
Average	$413	$450	$78	$35	$976
Percentage of total	42	46	8	4	....

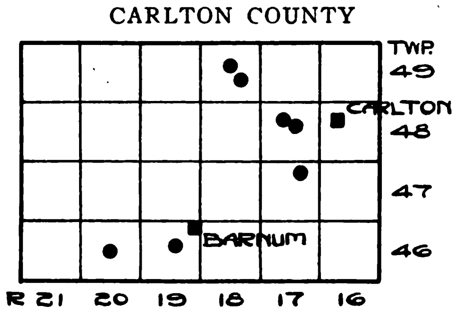

Fig. 4. Location of Coöperating Farms in Carlton County

TABLE XVI

Cash Required to Start and Facts Concerning Land Clearing on 7 Farms in Carlton County

Farm No.	Year settled	Estimated Cash required		No. acres cleared when farm was taken	Average No. acres cleared annually	Total acres cleared to 1917	Estimated cost of clearing per acre
		When settled	At present				
1	1902	$1,000	$2,000	0	5.5	48	$30
2	1888	80	2,000	2	1.5	75	75
3	1902	None	500	0	2.5	25	50
4	1909	800	800	2	4.0	65	30
5	1909	None	800	0	2.0	15	30
6	1884	None	500	2	4.0	85	60
7	1913	1,500	2,000	0	10.0	50	30
Average	....	$625	$1,085	2 (3)	4.2	52	$44

TABLE XVII

Crop Statistics on 7 Farms in Carlton County

Farm No.	Total acres in farm	No. acres unfit for agriculture	No. acres in crop	Percentage of farm in crop	Annual cash receipts from crops	Crops grown last few years
1	115	0	28.0	24	$1,682	Oats, barley, potatoes, rutabagas, hay
2	160	45	28.5	18	275	Oats, potatoes, hay
3	80	0	18.0	22	0	Oats, potatoes, hay
4	80	0	38.0	47	680	Oats, potatoes, hay, cabbage, rutabagas
5	80	0	3.0	4	0	Oats, hay
6	160	0	42.0	26	70	Oats, wheat, barley, hay
7	160	100	31.0	19	1,300	Oats, wheat, rye, potatoes
Average.	120	....	27	22	$572	....

TABLE XVIII

Livestock Statistics on 7 Farms in Carlton County

Farm No.	No. of stock on hand April 1—first year record was taken						Annual cash receipts from stock
	Horses	Cows	Other cattle	Hogs	Poultry	Sheep	
1	3	5	....	10	75	0	$861
2	2	2	....	....	10	0	400
3	3	13	....	3	40	0	1,040
4	7	5	7	18	....	0	440
5	4	....	5	....	40	0	0
6	2	14	9	....	30	0	1,340
7	2	1	1	13	40	0	120
Average.	3	6	5	11	40	0	$600

TABLE XIX

Distribution of Income on 7 Farms in Carlton County

Farm No.	Income from				Total
	Crops	Livestock	Forest products	Outside labor	
1...........................	$1,682	$861	0	$ 100	$2,643
2...........................	275	400	37	0	712
3...........................	0	1,040	0	300	1,340
4...........................	680	440	0	0	1,120
5...........................	0	0	0	600	600
6...........................	70	1,340	0	0	1,410
7...........................	1,300	120	150	0	1,570
Average..................	$563	$603	$28	$147	$1,341
Percentage of total.........	42	45	2	11	....

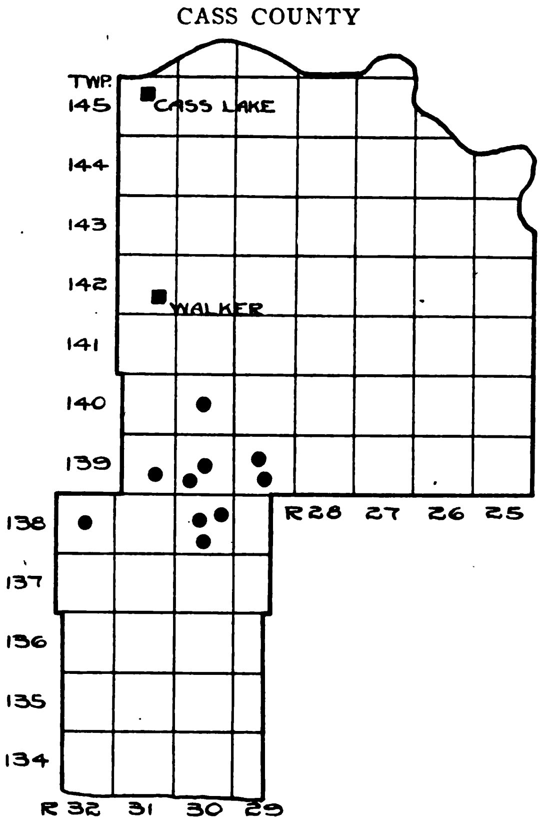

Fig. 5. Location of Coöperating Farms in Cass County

TABLE XX

Cash Required to Start and Facts Concerning Land Clearing on 10 Farms in Cass County

Farm No.	Year settled	Cash required		No. acres cleared when farm was taken	Average No. acres cleared annually	Total No. acres cleared to 1917	Estimated cost of clearing per acre
		When settled	At present				
1	1912	None	$700	0	10.0	35	$50.00
2	1900	$50	2,000	0	12.0	140	10.00
3	1910	100	500	0	12.0	65	30.00
4	1913	400	2,000	0	7.5	32	25.00
5	1895	5	2,000	0	3.0	40	25.00
6	1916	None	100	30	2.0 (1 year)	32	20.00
7	1905	500	250	6	6.0	35	20.00
8	1913	150	....	0	6.0	23	50.00
9	1905	None	....	20	15.0	250	20.00
10	1908	50	500	7	1.5	12	15.00
Average	....	$204 (4)	$1,000	16 (4)	7.0	66	$26.50

TABLE XXI

Crop Statistics on 10 Farms in Cass County

Farm No.	Total acres in farm	No. acres unfit for agriculture	No. acres in crop	Percentage of farm in crop	Annual cash receipts from crops	Crops grown last few years
1	160	0	....	....	0	Oats, corn, potatoes
2	520	20	140	27	0	Oats, corn, potatoes
3	114	5	34	30	$ 100	Corn, oats, clover, potatoes
4	160	0	23	22	357	Corn, oats, potatoes, beans
5	160	0	24	15	519	Oats, rye, potatoes, cabbage
6	....	0	30	....	100	Hay
7	160	0	25	16	50	Oats, potatoes, rutabagas
8	80	0	15	19	25	Oats, corn, hay, rutabagas
9	500	50	113	22	1,400	Oats, wheat, rye, clover, potatoes
10	40	0	19	47	34	Oats, corn, potatoes, flax
Average	210	....	35	17	$258	....

TABLE XXII

Livestock Statistics on 10 Farms in Cass County

Farm No.	No. of stock on hand April 1—first year record was taken						Annual cash receipts from stock
	Horses	Cows	Other cattle	Hogs	Poultry	Sheep	
1	4	3	....	4	70	0	$100
2	5	....	34	30	....	0	777
3	2	7	1	....	....	0	300
4	2	11	....	11	....	0	....
5	2	3	....	18	....	0	25
6	2	2	3	....	....	0	75
7	3	....	....	....	60	0	110
8	1	2	3	....	....	0	50
9	8	....	26	24	....	*	340
10	3	6	13	2	30	0	264
Average	3	5	13	15	50 (3)	0	$227

* 240 goats.

TABLE XXIII

Distribution of Income on 10 Farms in Cass County

Farm No.	Income from				Total
	Crops	Livestock	Forest products	Outside labor	
1	0	$100	$195 (logging)	$1,400	$1,695
2	0	777	650	0	1,427
3	100	300	0	0	400
4	357	....	32	0	....
5	519	25	0	30	574
6	100	75	0	0	175
7	50	110	225	0	385
8	25	50	175	46	296
9	1,400	340	0	0	1,740
10	34	264	0	85	383
Average	$358	$227	$130	$154	$769
Percentage of total	33	30	17	20	....

HUBBARD COUNTY

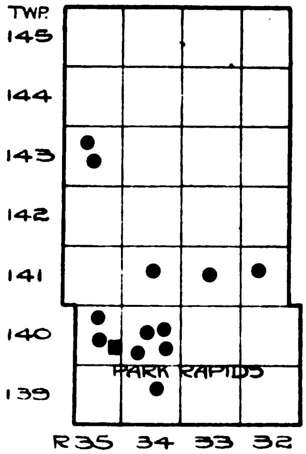

Fig. 6. Location of Coöperating Farms in Hubbard County

TABLE XXIV
Cash Required to Start and Facts Concerning Land Clearing on 12 Farms in Hubbard County

Farm No.	Year settled	Cash required		No. acres cleared when farm was taken	Average No. acres cleared annually	Total No. acres cleared to 1917	Estimated cost of clearing per acre
		When settled	At present				
1	1882	None	$800	90	11.0	250	$15.00
2	1886	None	....	0	2.5	90	10.00
3	1900	None	500	35	12.5	120	12.00
4	1889	$250	1,000	0	9.0	60	....
5	1902	None	700	0	3.5	82	15.00
6	1908	400	700	0	8.0	60	12.00
7	1894	30	1,000	0	4.0	80	20.00
8	1905	30	500	0	6.0	25	25.00
9	1898	1,000	1,000	140	25.0	240	10.00
10	1897	None	600	80	7.0	130	16.00
11	1905	None	1,500	10	12.0	148	20.00
12	1914	200	300	0	20.0	60	20.00
Average	....	$280	$780	71 (5)	7.0	112	$15.00

TABLE XXV
Crop Statistics on 12 Farms in Hubbard County

Farm No.	Total acres in farm	No. acres unfit for agriculture	No. acres in crop	Percentage of farm in crop	Annual cash receipts from crops	Crops grown last few years
1	365	0	250	68	$1,278	Oats, wheat, corn, rye, clover, potatoes
2	160	10	52	33	912	Oats, wheat, corn, rye, clover, potatoes
3	160	0	125	78	684	Oats, corn, rye, potatoes
4	160	0	62	39	162	Wheat, oats, corn, beans, potatoes, clover
5	160	0	45	28	1,480	Corn, clover seed, potatoes, onions
6	200	0	66	33	1,175	Oats, corn, clover seed, potatoes
7	233	0	87	37	120	Oats, wheat, corn, potatoes
8	160	20	27	17	142	Oats, wheat, rye, hay
9	240	0	220	92	1,875	Oats, wheat, rye, corn, hay
10	160	0	104	65	10	Oats, corn, potatoes, hay
11	160	0	148	93	361	Oats, wheat, barley, rye, hay
12	200	0	60	30	0	Potatoes, beans, hay
Average	196	....	86	44	$700	....

TABLE XXVI
LIVESTOCK STATISTICS ON 12 FARMS IN HUBBARD COUNTY

Farm No.	No. of stock on hand April 1—first year record was taken						Annual cash receipts from stock
	Horses	Cows	Other cattle	Hogs	Poultry	Sheep	
1	6	....	26	14	75	0	$600
2	2	5	4	2	75	0	515
3	5	....	40	5	90	75	1,067
4	2	2	6	2	75	0	182
5	2	....	22	....	40	0	500
6	4	7	10	....	50	25	855
7	4	....	20	18	40	2	1,000
8	1	4	7	7	....	0	300
9	5	10	15	12	40	0	1,910
10	19	....	42	48	40	24	2,376
11	7	....	60	16	60	6	1,923
12	5	7	....	7	60	0	450
Average.	4	6 (6)	23	13	60	26 (5)	$973

TABLE XXVII
DISTRIBUTION OF INCOME ON 12 FARMS IN HUBBARD COUNTY

Farm No.	Income from				Total
	Crops	Live-stock	Forest products	Outside labor	
1	$1,278	$600	0	0	$1,878
2	912	515	0	0	1,427
3	684	1,067	0	0	1,751
4	162	182	280	0	624
5	1,480	500	0	25	2,005
6	1,175	855	350	300	2,680
7	120	1,000	0	0	1,120
8	142	300	0	250	692
9	1,875	1,910	120	0	3,905
10	10	2,376	0	0	2,386
11	361	1,923	0	0	2,284
12	0	450	0	600	1,050
Average	$700	$973	$68	$92	$1,833
Percentage of total	38	53	4	5	....

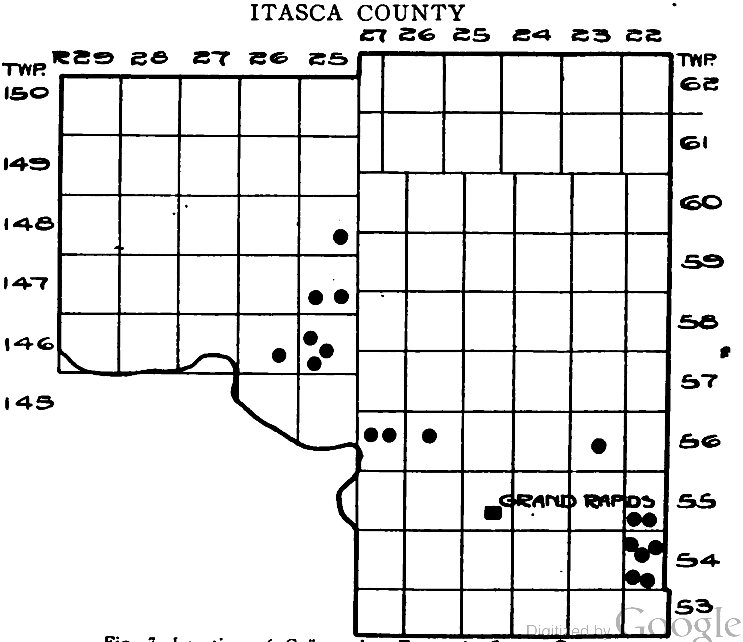

Fig. 7. Location of Coöperating Farms in Itasca County

TABLE XXVIII

CASH REQUIRED TO START AND FACTS CONCERNING LAND CLEARING ON 18 FARMS IN ITASCA COUNTY

Farm No.	Year settled	Cash required		No. acres cleared when farm was taken	Average No. acres cleared annually	Total No. acres cleared to 1917	Estimated cost of clearing per acre
		When settled	At present				
1	1904	None	$1,500	0	5.0	25.0	$65
2	1906	$200	2,500	0	1.5	25.0	50
3	1911	100	1,500	0	4.5	22.0	80
4	1905	None	800	0	1.0	25.0	25
5	1913	1,300	500	0	2.5	7.5	100
6	1887	None	250	0	1.0	18.0	39
7	1904	1,100	1,000	0	7.5	39.0	20
8	1915	3,400	5,000	0	11.0	33.0	25
9	1915	1,500	3,000	0	5.5	17.0	30
10	1916	2,000	4,000	0	3.5	7.0	20
11	1910	None	500	0	4.0	20.0	20
12	1914	None	3,000	1	....	38.0	25
13	1908	300	2,000	0	1.2	10.0	75
14	1907	....	....	0	2.0	12.0	25
15	1911	500	1,000	0	6.0	38.0	20
16	1907	....	....	0	2.5	30.0	25
17	1896	None	50	0	2.0	30.0	40
18	1915	....	....	0	1.0	3.0	40
Average	....	$650	$1,660	0	3.0	23.0	$40

TABLE XXIX

CROP STATISTICS ON 18 FARMS IN ITASCA COUNTY

Farm No.	Total acres in farm	No. acres unfit for agriculture	No. acres in crop	Percentage of farm in crop	Annual cash receipts from crops	Crops grown last few years
1	200	30	25	12.5	$650	Oats, barley, potatoes, hay
2	80	2	8	10.0	661	Potatoes, rutabagas, strawberries, hay
3	80	5	11	13.0	243	Oats, beans, beets, potatoes, hay
4	120	26	14	12.0	262	Oats, barley, potatoes, hay
5	83	7	4	5.0	80	Oats, barley, potatoes, hay
6	160	0	20	12.5	250	Oats, hay
7	145	0	38	26.0	0	Oats, hay
8	160	25	25	16.0	100	Oats, barley, potatoes, hay
9	160	0	11	7.0	100	Oats, potatoes, hay
10	180	22	6	3.0	102	Potatoes, hay
11	120	0	15	12.5	432	Hay
12	80	0	21	21.0	60	Wheat, oats, barley, potatoes, hay
13	45	0	1	2.0	20	Potatoes, strawberries
14	80	0	10	12.5	41	Potatoes, hay
15	400	200	14 (20 hay)	7.0	0	Oats, barley, potatoes, hay, rutabagas
16	40	0	29	72.0	16	Oats, potatoes, hay, rutabagas
17	240	0	20	8.0	150	Hay
18	40	0	3	1.5	0	Potatoes, hay
Average	134	....	15	11.0	$165	....

TABLE XXX

LIVESTOCK STATISTICS ON 18 FARMS IN ITASCA COUNTY

Farm No.	No. of stock on hand April 1—first year record was taken						Annual cash receipts from stock
	Horses	Cows	Other cattle	Hogs	Poultry	Sheep	
1	3	4	....	32	40	0	$671
2	2	8	....	13	75	0	503
3	2	3	....	5	30	0	135
4	4	5	....	4	73	0	163
5	2	2	4	....	....	0	130
6	3	1	....	2	40	0	55
7	3	25	....	25	40	0	675
8	3	7	....	9	....	0	284
9	4	4	....	6	15	0	280
10	5	5	....	2	30	0	440
11	....	2	7	2	100	0	0
12	2	2	3	1	25	0	175
13	....	2	4	....	25	0	228
14	1	1	....	....	....	0	18
15	4	12	35	8	200	0	1,095
16	2	....	1	2	....	0	240
17	5	....	10	....	50	0	160
18	1	2	3	1	....	0	60
Average.	3	5.6	9 (7)	8 (13)	57 (13)	0	$394

TABLE XXXI

DISTRIBUTION OF INCOME ON 18 FARMS IN ITASCA COUNTY

Farm No.	Income from				Total
	Crops	Live-stock	Forest products	Outside labor	
1	$650	$671	$330	0	$1,651
2	661	503	210	0	1,374
3	243	135	140	0	518
4	262	163	207	0	632
5	80	130	0	$106	316
6	250	55	250	550	1,105
7	0	675	900	900 (logging)	2,475
8	100	284	112	0	496
9	100	280	0	0	380
10	102	440	0	0	542
11	432	0	582	0	1,014
12	60	175	150	100	485
13	20	228	455	350	1,053
14	41	18	123	297	479
15	0	1,095	0	0	1,095
16	16	240	20	100	376
17	150	160	0	1,200 (logging)	1,510
18	0	60	320	2,000 (logging)	2,380
Average	$165	$394	$216	$306	$1,081
Percentage of total	15	36	20	29	....

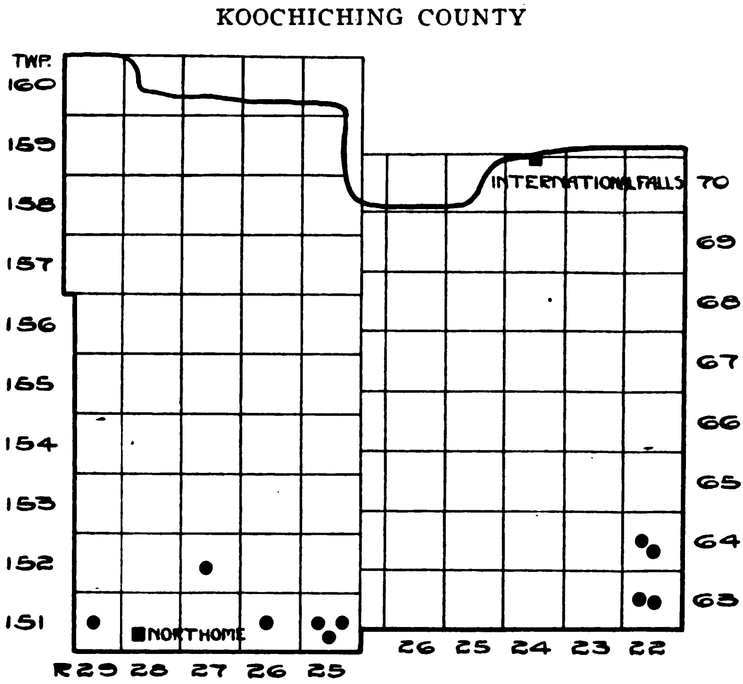

Fig. 8. Location of Coöperating Farms in Koochiching County

TABLE XXXII

Cash Required to Start and Facts Concerning Land Clearing on 10 Farms in Koochiching County

Farm No.	Year settled	Estimated Cash required		No. acres cleared when farm was taken	Average No. acres cleared annually	Total No. acres cleared to 1917	Estimated cost of clearing per acre
		When settled	At present				
1	1906	$200	$1,000	0	5.5	28	$25.00
2	1906	900	....	0	1.5	17	25.00
3	1909	100	1,000	0	2.5	15	40.00
4	1907	2,000	75,000	0	3.0	36	60.00
5	1902	None	....	0	1.0	30	60.00
6	1904	None	1,500	0	1.5	10	50.00
7	1907	100	500	0	1.0	15	60.00
8	1902	....	....	10	2.0	50	60.00
9	1901	200	1,000	25 (hay)	1.0	15	60.00
10	1899	35	1,000	0	1.0	15	35.00
Average.	....	$440 (8)	1,000 (6)	0	2.2	25	$47.50

TABLE XXXIII

CROP STATISTICS ON 10 FARMS IN KOOCHICHING COUNTY

Farm No.	Total acres in farm	No. acres unfit for agriculture	No. acres in crop	Percentage of farm in crop	Annual cash receipts from crops	Crops grown last few years
1	160	0	....	....	....	No report
2	160	0	....	....	0	Potatoes, hay, oats
3	160	0	9.0	5.5	$15	Potatoes, hay, oats, wheat, carrots
4	160	0	56.0	35.0	75	Potatoes, hay, oats, wheat, barley
5	180	0	19.0	11.0	75	Potatoes
6	80	0	0.5	0.6	50	Potatoes
7	160	0	6.0	4.0	0	Wheat, barley, potatoes
8	120	0	18.0	15.0	....	Wheat, oats, corn, potatoes, hay
9	160	0	15.0	9.0	60	Grain, hay
10	160	0	6.5	4.0	50	Oats, speltz, potatoes
Average	150	....	18.0	12.0	$46 (7)	....

TABLE XXXIV

LIVESTOCK STATISTICS ON 10 FARMS IN KOOCHICHING COUNTY

Farm No.	No. of stock on hand April 1—first year record was taken						Annual cash receipts from stock
	Horses	Cows	Other cattle	Hogs	Poultry	Sheep	
1	2	....	....	....	....	0	....
2	2	2	....	....	24	0	$21
3	1	2	1	2	....	0	0
4	7	3	12	25	60	0	1,100
5	2	....	15*	....	40	0	680
6	0	1	2	....	40	0	100
7	1	6	10	3	....	0	612
8	8	7	18	....	....	0	....
9	2	4	....	....	50	0	72
10	2	2	3	2	25	12	196
Average	3	3.5 (8)	6 (8)	8 (4)	40 (6)	....	$44 (7)

* Includes milk cows.

TABLE XXXV

DISTRIBUTION OF INCOME ON 10 FARMS IN KOOCHICHING COUNTY

Farm No.	Income from				Total
	Crops	Livestock	Forest products	Outside labor	
1	....	....	....	....	....
2	....	....	....	....	....
3	$15	0	$575	$0	$590
4	75	$1,100	0	0	1,175
5	75	680	0	0	755
6	50	100	89	75	314
7	0	612	480	250	1,342
8	0	....	840	....	....
9	60	72	1,168	....	1,300
10	50	196	....	100	346
Average	$46	$390	$250	$145	$831
Percentage of total	6	47	30	17	....

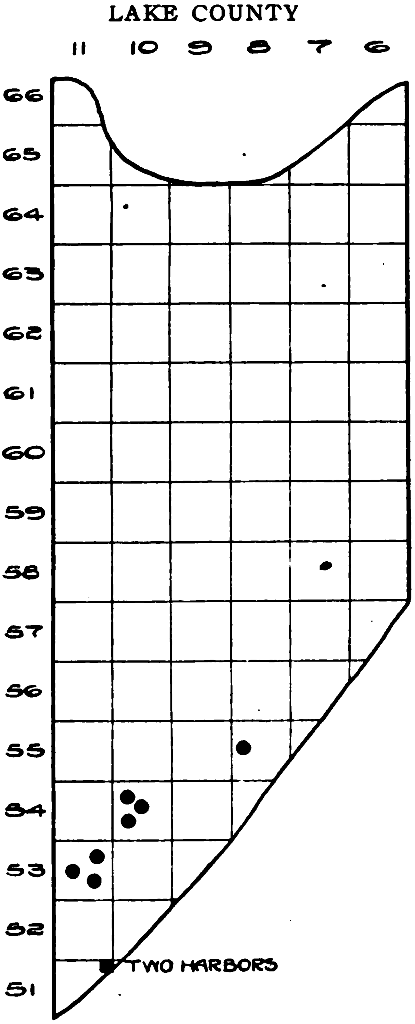

Fig. 9. Location of Coöperating Farms in Lake County

TABLE XXXVI

Cash Required to Start and Facts Concerning Land Clearing on 7 Farms in Lake County

Farm No.	Year settled	Cash required		No. acres cleared when farm was taken	Average No. acres cleared annually	Total No. acres cleared to 1917	Estimated cost of clearing per acre
		When settled	At present				
1	1906	$100	....	0	2.0	16	$50
2	1896	None	$1,000.	0	2.5	45	75
3	1909	500	800	0	2.0	15	75
4	1896	None	2,000	0	1.5	30	65
5	1915	300	....	0	3.0	6	60
6	1906	100	....	0	2.0	16	50
7	1902	None	....	0	5.0	25	40
Average.	....	$250	$1,300 (3)	0	2.5	22	$60

TABLE XXXVII

CROP STATISTICS ON 7 FARMS IN LAKE COUNTY

Farm No.	Total acres in farm	No. acres unfit for agri-culture	No. acres in crop	Per-centage of farm in crop	Annual cash receipts from crops	Crops grown last few years
1	77	0	20.0	26	$25	Oats, potatoes, hay
2	160	0	29.5	18	90	Oats, potatoes, hay
3	40	0	11.5	29	....	Potatoes, hay
4	160	0	23.0	14	200	Oats, wheat, potatoes, truck
5	160	0	27.0	17	0	Oats, potatoes, hay
6	77	0	20.0	26	25	Oats, potatoes, hay
7	100	0	25.0	25	0	Oats, potatoes, hay
Average	110	....	21.0	19	$60	....

TABLE XXXVIII

LIVESTOCK STATISTICS ON 7 FARMS IN LAKE COUNTY

Farm No.	No. of stock on hand April 1—first year record was taken						Annual cash receipts from stock
	Horses	Cows	Other cattle	Hogs	Poultry	Sheep	
1	2	5.0	....	....	25	....	$250
2	3	5.0	10.0	....	....	....	....
3	2	....	6.0	....	....	....	....
4	1	5.0	....	....	75	....	350
5	4	2.0	0	....	20	....	0
6	2	5.0	....	....	20	....	....
7	2	6.0	....	2	30	....	820
Average	3	3.5	5.5 (3)	....	30	....	$236

TABLE XXXIX

DISTRIBUTION OF INCOME ON 7 FARMS IN LAKE COUNTY

Farm No.	Income from				Total
	Crops	Live-stock	Forest products	Outside labor	
1	$25	$250	0	$200	$475
2	90	0	0	0	....
3	....	....	....	....	....
4	200	350	0	0	550
5	0	0	0	300	300
6	25	0	0	200	225
7	0	820	0	200	1,020
Average	$60	$236	0	$150	$446
Percentage of total	13	53	0	34	....

ST. LOUIS COUNTY, DISTRICT NO. 1

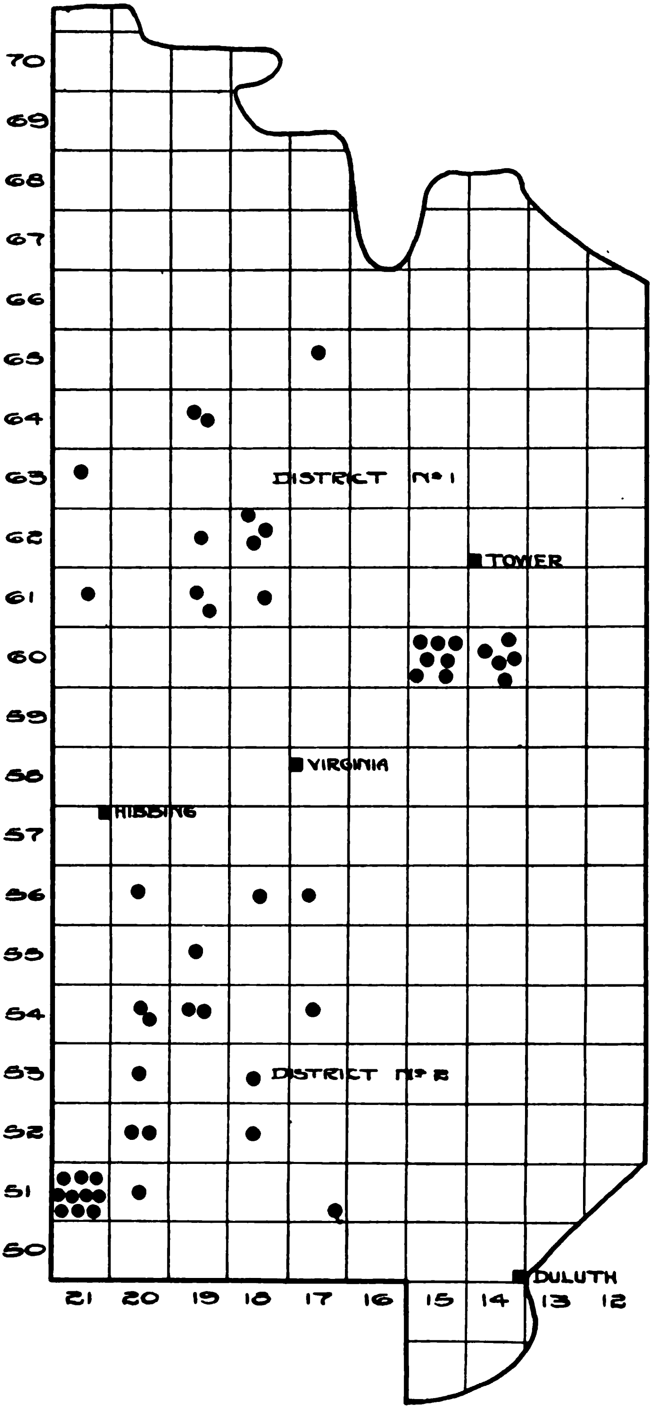

Fig 10. Location of Coöperating Farms in St. Louis County

TABLE XL

CASH REQUIRED TO START AND FACTS CONCERNING LAND CLEARING ON 24 FARM IN DISTRICT NO. 1, ST. LOUIS COUNTY

Farm No.	Year settled	Cash required		No. acres cleared when farm was taken	Average No. acres cleared annually	Total No. acres cleared to 1917	Estimated cost of clearing per acre
		When settled	At present				
1	1899	None	....	0	2.0	60	$100
2	1906	None	....	0	1.5	20	175
3	1901	None	....	0	2.0	40	60
4	1900	$50	None	0	1.5	30	75
5	1901	18	$500	0	1.0	40	100
6	1901	20	400	0	1.0	15	100
7	1905	....	....	0	2.0	30	....
8	1905	....	....	0	2.0	25	25
9	1905	....	....	0	1.5	25	30
10	1904	None	500	0	1.5	25	60
11	1908	....	....	0	3.0	25	40
12	1912	....	....	0	3.0	10	30
13	1903	....	....	0	3.0	20	30
14	1900	50	....	0	4.0	100	50
15	1903	None	....	0	3.0	40	25
16	1899	....	....	0	2.0	....	....
17	1896	None	300	0	2.0	50	60
18	1908	900	900	0	5.0	40	50
19	1907	....	....	0	4.0	35	50
20	1902	None	4,000	0	2.5	35	18
21	1909	50	500	0	2.0	10	75
22	1908	None	....	0	6.0	64	40
23	1912	None	400	0	1.0	5	50
24	1909	50	500	0	2.0	10	75
Average.	....	$30	$440	0	2.4	33	$60

TABLE XLI

CROP STATISTICS ON 24 FARMS IN DISTRICT NO. 1, ST. LOUIS COUNTY

Farm No.	Total acres in farm	No. acres unfit for agriculture	No. acres in crop	Percentage of farm in crop	Annual cash receipts from crops	Crops grown last few years
1	160	60	15	9.0	$48	Barley, hay, potatoes
2	160	40	9	5.5	11	Wheat, rye, oats, hay, potatoes
3	120	0	20	12.0	36	Barley, oats, hay, potatoes
4	120	0	8	6.5	35	Hay, potatoes
5	160	60	11	7.0	18	Wheat, hay, potatoes
6	160	60	11	7.0	60	Wheat, hay, potatoes
7	160	80	2	1.2	30	Oats, hay, potatoes
8	160	0	18	16.0	....	Oats, hay, potatoes
9	40	0	25	62.0	540	Barley, oats, hay, potatoes
10	160	35	13	8.0	....	Oats, hay, potatoes
11	40	0	10	25.0	70	Oats, hay, potatoes
12	40	10	4	10.0	....	Oats, hay, potatoes
13	160	10	3	2.0	15	Potatoes
14	120	3	29	24.0	....	Wheat, oats, barley, potatoes
15	160	40	29	18.0	....	Oats, hay, potatoes
16	160	122	....	....	....	No report
17	160	110	50	31.0	....	Clover, corn, wheat, oats, potatoes
18	160	0	24	15.0	3	Oats, barley, hay, potatoes
19	160	20	22	14.0	....	Oats, hay, potatoes
20	200	0	19	9.5	....	Oats, hay, potatoes
21	160	0	12	7.5	200	Wheat, oats, barley, hay, potatoes
22	120	0	....	....	90	Wheat, oats, barley, hay, potatoes
23	40	0	1	....	....	Potatoes
24	160	60	12	7.5	200	Oats, hay, potatoes
Average.	133	60	18	13.0	$72	....

TABLE XLII

LIVESTOCK STATISTICS ON 24 FARMS IN DISTRICT NO. 1, ST. LOUIS COUNTY

Farm No.	No. of stock on hand April 1—first year record was taken						Annual cash receipts from stock
	Horses	Cows	Other cattle	Hogs	Poultry	Sheep	
1	2	5	6	2	50		$765
2	1	3	5		13		25
3	2	4	6		12		
4	1	4	6				185
5	2	4	3		48		72
6	1	5	5	1	15		138
7	2	4	3	1	50		215
8	3	3	10	1	30		690
9	1	3	2		40		75
10	1	3	4		30		153
11	1	5	5	1			100
12	1	1	2		5		
13	2	1	3			2	48
14	2	7		20	33		
15	3	5			35		
16	3	10	6	4	60		
17	6	10	5	3	50		1,200
18	2	2	4				
19							
20	3	3		23			168
21	2*	3			40		88
22	2	5	8	9	100		860
23							
24	2*	4	3	4	86		50
Average	2	4	5	6	36		$252

*Oxen

TABLE XLIII

DISTRIBUTION OF INCOME ON 24 FARMS IN DISTRICT NO. 1, ST. LOUIS COUNTY

Farm No.	Income from				Total
	Crops	Live-stock	Forest products	Outside labor	
1	$48	$765	$825		$1,638
2	11	25	150	$10	196
3	36		800		836
4	35	185	125	70	415
5	18	72		300	390
6	60	138		150	348
7	30	215			245
8		690	2,700	30	3,420
9	540	75			615
10		153	360	100	612
11	70	100			170
12			235	100	335
13	15	48	475	40	578
14					
15					
16					
17		1,200	600		1,800
18	3		144		147
19					
20		168			168
21	200	88	200		488
22	90	860			950
23				400	400
24	200	50	200		450
Average	$72	$252	$360	$37	$721
Percentage of total	10	35	50	5	

ST. LOUIS COUNTY, DISTRICT NO. 2

TABLE XLIV

Cash Required to Start and Facts Concerning Land Clearing on 26 Farms in District No. 2, St. Louis County

Farm No.	Year settled	Cash required		No. acres cleared when farm was taken	Average No. acres cleared annually	Total No. acres cleared to 1917	Estimated cost of clearing per acre
		When settled	At present				
1	1891	$75	$1,000	0	2.0	160	$120
2	1905	None	1,000	0	5.0	65	65
3	1902	600	1,000	0	4.0	20	50
4	1914	1,000	1,400	0	2.0	4	25
5	1911	100	800	0	2.5	10	35
6	1913	160	1,000	0	20.0	60	17
7	1902	....	....	0	4.0	54	30
8	1902	40	600	0	3.0	30	50
9	1898	25	250	0	4.0	80	40
10	1894	600	600	0	3.0	35	35
11	1895	400	500	0	4.0	30	35
12	1896	....	....	0	4.0	35	28
13	1900	500	500	0	2.5	15	42
14	1896	250	250	0	4.0	35	45
15	1896	350	500	0	3.0	30	35
16	1900	42	250	0	2.5	16	35
17	1902	150	250	0	1.5	10	35
18	1902	500	500	0	2.0	32	32
19	1902	350	500	4	3.0	42	32
20	1905	250	250	0	2.5	44	26
21	1903	475	475	0	1.5	23	30
22	1897	25	500	0	1.5	33	30
23	1905	150	450	0	2.0	18	25
24	1906	....	....	0	3.0	10	....
25	1905	....	....	0	1.5	12	50
26	1904	50	100	0	1.0	18	25
Average	....	$256	$510	0	2.5	31	$35

TABLE XLV

Crop Statistics on 26 Farms in District No. 2, St. Louis County

Farm No.	Total acres in farm	No. acres unfit for agriculture	No. acres in crop	Percentage of farm in crop	Annual cash receipts from crops	Crops grown last few years
1	520	0	....	....	....	....
2	160	0	50.0	31	$360	Oats, potatoes, hay
3	80	5	20.0	25	30	Beets, beans, onions, hay, potatoes, oats
4	40	0	2.0	5	0	Beets, beans, onions, hay, potatoes, oats, cabbage
5	40	0	10.0	25	0	Potatoes, hay
6	103	5	63.0	61	221	Potatoes, carrots, rutabagas, hay
7	320	0	38.0	12	60	Potatoes, oats, hay
8	120	0	22.0	18	0	Potatoes, oats, rye
9	240	0	40.0	17	0	Potatoes, oats, hay
10	160	0	15.0	9	0	Potatoes, oats, rye, hay
11	160	0	17.0	11	125	Potatoes, oats, hay
12	120	0	18.0	15	63	Potatoes, oats, hay
13	80	0	13.0	16	50	Potatoes, oats
14	160	0	18.0	11	....	Potatoes, oats, hay
15	134	0	21.0	16	0	Potatoes, oats, hay
16	80	0	14.5	18	180	Oats, potatoes, hay
17	40	0	9.5	24	0	Oats, potatoes, hay
18	80	0	32.5	41	210	Oats, potatoes, hay
19	120	0	40.0	33	....	Oats, potatoes, hay
20	80	0	43.0	53	0	Oats, potatoes, hay, rye
21	80	0	23.5	30	0	Oats, potatoes, hay, rutabagas
22	80	0	32.0	40	0	Oats, potatoes, hay
23	120	0	17.5	15	0	Oats, potatoes, hay
24	40	5	10.0	25	200	Potatoes, hay
25	80	0	7.5	9	0	Potatoes, hay
26	94	0	18.0	19	200	Wheat, oats, potatoes, hay
Average	108	....	24.0	22	$72	....

TABLE XLVI

LIVESTOCK STATISTICS ON 26 FARMS IN DISTRICT NO. 2, ST. LOUIS COUNTY

Farm No.	No. of stock on hand April 1—first year record was taken						Annual cash receipts from stock
	Horses	Cows	Other cattle	Hogs	Poultry	Sheep	
1	....	....	....	....	....	....	....
2	2	3	7	....	....	....	$33
3	1	3	....	3	10	....	848
4	4	3	....	2	25	....	50
5	1	4	3	2	20	....	44
6	2	....	....		60	....	14
7	2	7	10	....	....	4	365
8	4	6	2	....	13	....	....
9	4	8	....	....	....	....	....
10	2	....	....	....	....	....	....
11	2	6	4	1	....	....	....
12	3	8	6	11	....	....	....
13	1	6	4	....	....	....	....
14	2	8	6	....	....	....	....
15	2	8	5	....	....	2	....
16	2	0	0	0	0	0	0
17	3	8	12	....	25	....	419
18	2	7	6	....	50	....	352
19	2	8	13	....	45	....	185
20	3	8	9	....	....	....	375
21	1	8	8	....	40	....	415
22	1	6	9	....	35	....	220
23	2	5	8	....	....	....	150
24	1	4	3	4	86	....	586
25	1	3	2	2	....	....	550
26	2	4	....	....	30	....	128
Average.	2	6	6 (23)	2 (6)	44 (18)	3 (2)	$284 (16)

TABLE XLVII

DISTRIBUTION OF INCOME ON 26 FARMS IN DISTRICT NO. 2, ST. LOUIS COUNTY

Farm No.	Income from				Total
	Crops	Live-stock	Forest products	Outside labor	
1....................	....	....	....	....	....
2....................	$360	$33	$0	$0	$393
3....................	30	848	270	0	1,148
4....................	0	50	0	300	350
5....................	0	44	0	33	77
6....................	221	14	319	175	729
7....................	60	365	241	0	666
8....................	....	....	....	....	....
9....................	....	....	350	....	350*
10....................	....	....	120	....	120*
11....................	125	....	....	....	125*
12....................	63	....	....	....	63*
13....................	50	....	....	....	50*
14....................	....	....	....	....	....
15....................	....	....	....	....	....
16....................	180	0	0	0	180
17....................	0	419	0	0	419
18....................	210	352	403	0	965
19....................	0	185	745	0	930
20....................	0	375	450	0	825
21....................	0	415	0	0	415
22....................	0	220	180	0	400
23....................	0	150	900	0	1,050
24....................	2C0	586	0	190	976
25....................	0	550	180	75	805
26....................	200	128	1,340	600 (logging)	2,268
Average....................	$72	284	332	52	738
Percentage of total.........	10	38	45	7	....

* Not in average.

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The University of Minnesota

AGRICULTURAL EXPERIMENT STATION

STUDIES ON FUSARIUM DISEASES OF POTATOES AND TRUCK CROPS IN MINNESOTA

TECHNICAL

BY

G. R. BISBY

DIVISION OF PLANT PATHOLOGY AND BOTANY

UNIVERSITY FARM, ST. PAUL

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STUDIES ON FUSARIUM DISEASES OF POTATOES AND TRUCK CROPS IN MINNESOTA

By G. R. BISBY

INTRODUCTION

Fusarium wilt was reported (72) as causing a loss of more than twenty-five million bushels, or 4.54 per cent of the potato crop of the United States in 1917. Despite the large damage due to *Phytophthora infestans* in this country the same year, the total loss reported from Fusarium wilt was greater. Besides the injury from wilt, Fusarium tuber rots in the field, in storage, and during transportation may destroy from 10 to 50 per cent of the crop (37, 43, 72, 75).

Minnesota is one of the states in which typical Fusarium wilt has been serious. Certain symptoms atypical of wilt have also been under observation for some time, particularly in the Red River Valley. The study of this rather anomalous disease has received particular attention. Fusarium dry rot was also found to present, in Minnesota, certain phases not emphasized heretofore. The writer has also studied certain Fusarium diseases of other truck crops as well as those of the potato.

The genus Fusarium was established by Link in 1809 (34). Various changes in the use of generic and specific names for the fungi in question were made during the succeeding century; the species added were often imperfectly described, and the host or substratum served frequently as the chief distinguishing diagnostic character. Smith and Swingle in 1904 (63) were forced to revert to the oldest available name to designate the Fusarium on potato, viz., *F. oxysporum* Schlechtendal, 1824. Appel and Wollenweber in 1910 (2) published a monograph of the genus Fusarium, and were able accurately to define several species. The literature to the year 1910 is also summarized. Wollenweber (76), Lewis (32), Sherbakoff (59), and others have also worked intensively on the Fusarium problem and described several new species. The name *Fusarium oxysporum* is, however, still applied to the fungus commonly causing wilt of potatoes.

MATERIALS AND METHODS

Isolations were made during the summers of 1916, 1917, and 1918 from potato plants showing various wilt symptoms. The plants were obtained from sections of Minnesota north of St. Paul, particularly the Red River Valley region. Several cultures of Fusaria isolated in 1914 and 1915 were furnished by A. G. Tolaas. During the winters, isolations were also made from rotted potato tubers. Isolations were made from garden beans and peas, sweet corn, cucurbits, and tomatoes. Several hundred cultures were studied and numerous inoculations were made in the laboratory, in the greenhouse, and in the field in 1917 and 1918.

Various culture media were used, particularly rice and potato plugs, sweet clover stems, the common agars for dilutions, and 5 and 10 per cent dextrose agar for color reactions. The ordinary methods of technique were used unless otherwise stated.

The writer wishes to express his thanks particularly to Dr. E. C. Stakman and Dr. E. M. Freeman, under whom the work was done, for suggestions and supervision. The writer is also indebted to A. G. Tolaas and Dr. W. A. Orton for cultures and other help, and to Dr. C. D. Sherbakoff for tentative corroboration of some determinations. The writer is particularly grateful to Dr. H. A. Edson of the United States Department of Agriculture who in his visits to Minnesota has freely given information and ideas.

The writer has submitted cultures of the various unidentified Fusaria to Dr. Sherbakoff for such taxonomic disposition as he sees fit.

POTATO WILT

HISTORICAL

Smith and Swingle (63) made the first detailed study of the wilt of potato caused by *Fusarium oxysporum*. The dry rot of tubers discussed by them is now generally considered to be caused chiefly by other species of Fusarium. They described in detail the effects of the wilt fungus on the plant and its entrance into and spread within the tuber. They studied the behavior of the fungus on various media. Control methods for wilt were suggested. While the earlier publication of Stewart (65) on "Another stem blight of potato" deals with a disease similar to wilt, Stewart (66) decided in 1898 that the blight was not communicable and "not caused by any vegetable organism," and recently stated, in letters dated Nov. 18 and 30, 1918, "While the symptoms point to Fusarium wilt, I doubt that it was actually that disease." However, "If it is true that tubers showing pronounced discoloration of the fibro-vascular bundles, owing to the infection with Fusarium wilt, do not usually produce affected plants, then there is some reason for believing that my Long Island stem-blight was in reality Fusarium wilt. The tubers which were planted in my experiments were all very definitely affected by the stem-end browning.

Every piece planted showed the stem-end browning. Accordingly, it seems to me that more diseased plants should have resulted." Clinton's description in 1895 (11) of a "Bundle blackening of tubers" may have been of the ring discoloration caused by *F. oxysporum*. He wrote in a letter dated Dec. 3, 1918, "While the tubers mentioned may quite likely have been connected with such a wilt, I have no positive information that they were."

Orton in 1909 (40) reported that the accumulation of *F. oxysporum* and other fungi in the peat soils of sections of California soon made the growing of potatoes unprofitable. Manns (36), as a result of his work, recommended clipping the stem ends of infected tubers. This is now a commonly used control method. Orton in 1914 (42), in comparing wilt due to *F. oxysporum* with leaf roll and other diseases, considered that wilt was "apparently a disease of warmer climates," altho he recognized that "in Minnesota wilt appears to be present in the older communities."

Discussing the occurrence of this disease in Europe, Appel (1, p. 143) states, "The [wilt] disease occurs in Germany also, but is of much less importance." Nicholls (38) reported the presence of *F. oxysporum* in Tasmania, and Carpenter (10) found this fungus in potato vines and tubers in Hawaii. Reports of *F. oxysporum* from other countries are doubtful, since this name has been loosely used.

Jones (27) found potato wilt especially in the older communities in Wisconsin. Milbrath (37) noted its seriousness in North Dakota, and its importance in Minnesota has been recognized for some time by Stakman and Tolaas (64). Kohler (30) may have referred to the stem end browning caused by *F. oxysporum,* tho it may be inferred that dry rot of tubers was also involved in the rot he attributed to "an undetermined species of Fusarium."

Carpenter (8), Link (33), and others have shown that *F. oxysporum* can produce a rot of potatoes. This is not in agreement with Wollenweber's (76) conclusion that members of the Elegans section of the genus Fusarium cause wilt but not rot. *F. eumartii* Carpenter, belonging to the section Martiella (76, p. 30), has been found by Haskell (20) and C. R. Orton (39) to cause a stem rot and wilt of potato plants, as well as a rot of the tubers. "Potato wilt" may, therefore, be due to more than one species of Fusarium, possibly following certain geographical limits. Orton (42) reported the symptoms of Verticillium wilt to be similar to those of Fusarium wilt and stated that the distribution of the former was restricted more particularly to the northern states. Verticillium wilt is reported (72) to be especially serious in Oregon. Appel (1) has noted (referring presumably particularly to Minnesota) symptoms atypical of the common potato wilt.

SYMPTOMOLOGY OF POTATO WILT CONDITIONS IN MINNESOTA

The symptoms have been fully described by other writers, and in general agree with those found under Minnesota conditions. Coons (13) recently noted that in Michigan the disease may exhibit two aspects; one, a rapid wilting in which the vine dies when the tubers are about half grown; and another characterized by the dying of the plants "at the close of the growing season." He found these symptoms to depend perhaps on whether the infection is from the seed piece or from the soil.

Figures 1 and 2 show the wilt symptoms common in Minnesota fields. Except in more severe cases, the plants do not begin to wilt until about blossoming time or later. The symptoms on the upper part of the plants are apparently those resulting from a considerable reduction in water supply. A cross-section of the lower stem reveals the browning of the vascular system and often of the other tissues as well. This browning may extend to the tips of the plants, tho the bundles are often free from hyphae in these upper discolored areas. The roots are usually affected seriously. The tubers, which have ordinarily had an opportunity to develop considerably before the wilting of the plant stops their growth, may be affected at the stem end, as fully described in the literature.

Atypical wilt symptoms such as those mentioned by Appel (1, p. 147) have received particular attention. Other observers had noticed these atypical symptoms, particularly in 1914 and 1915 in the Red River Valley, and had considered that they might be caused by the blackleg organism or some species of Fusarium. For convenience the term "foot rot" will be used to indicate the condition in question. The writer found some of this disease in 1916, practically none in 1917, but in August, 1918, it was found in Polk and Clay counties in the form more characteristic of that seen by Appel, Edson, Stakman, Orton, and others in 1914 and 1915.

Plants affected with foot rot are shown in Figures 3, 4, and 5. There is a dark brown or almost black discoloration of the lower and underground portions of the stem. These discolored areas are often rotted. When secondary organisms are present there may be a typical soft rot. While the symptoms resemble those of blackleg somewhat, there is not the inky black, slimy rot characteristic of blackleg. The disease is, however, confused with blackleg by growers and others.

There is a more abundant development of hyphae in the primary vessels and other tissues of the stem than in stems affected with ordinary wilt. The effect on the roots and stolons is similar to that on portions of the lower stem (see Figure 5). The stem end of the tuber may be attacked, and the way paved for invasion by secondary rotting organisms. The above-ground portions of the plant successively wilt, die, and eventually collapse. Fortunately this foot rot occurs more particularly late in the season, as is also ordinarily the case with wilt in Minnesota, so that a considerable crop of tubers may already have been produced. These tubers are, however, liable to suffer considerable injury before or during storage from the invasion of Fusaria and other organisms through the injured point of attachment of the tubers to the affected stolons.

The relation of this foot rot in Clay County, Minnesota, to the weather (United States Weather Record, Moorhead Station) during the 5 years this condition has been under observation is shown in Table I.

TABLE I

RELATION OF WEATHER TO THE DEVELOPMENT OF FOOT ROT

Year	Precipitation				Average temperature				Notes on the disease
	May	June	July	August	May	June	July	August	
	Inches	Inches	Inches	Inches	Degrees	Degrees	Degrees	Degrees	
1914	1.47	8.92	3.65	2.89	57.4	64.8	73.1	65.0	Abundant
1915	3.93	9.13	2.22	1.05	51.7	59.2	65.2	65.2	Present
1916	3.76	4.28	5.30	2.87	53.0	60.3	75.9	67.2	Present
1917	0.38	1.52	0.81	0.77	53.6	61.3	75.2	66.4	Absent
1918	2.73	1.79	2.68	4.90	55.0	64.4	67.7	69.4	Present late in season
Normal	2.95	4.13	3.74	3.10	54.8	64.14	68.7	65.9	

More than double the normal precipitation occurred in June, in 1914 and 1915. The rainfall was especially heavy in July, 1916. The season of 1917 was very dry, while in 1918 it was dry until late July and early August, when there was considerable precipitation. Moderately high temperature is also undoubtedly a factor in producing Fusarium wilt, altho, as shown by the temperature in July, 1917, the atypical foot rot does not occur as a result of high temperature without abundant rainfall; and as indicated in 1915, these symptoms may appear in a year of high precipitation even with temperatures considerably below normal. Observations indicate further that foot rot attacks the plants seriously only later in the season, even tho weather conditions from planting time on have been favorable to its development. Kohler (30) described Fusarium diseases of potato in Minnesota, and the foot rot condition may have been involved. He stated that "This disease does great havoc in wet years." Poor yields were obtained from planting tubers showing rot.

ETIOLOGY OF WILT OF POTATO IN MINNESOTA

The fungi isolated from various parts of wilted plants, particularly the interior of the stem near the surface of the soil, from several regions in Minnesota, especially the Red River Valley, were predominantly Fusaria. Verticillium was obtained in only a very few cases, and then in association with other organisms, indicating that it was only saprophytically or accidentally present. There was no evidence that Verticillium wilt is important in Minnesota. Most frequently the cultures obtained were determinable as *Fusarium oxysporum* by the character of their conidia, the salmon to lilac color of the medium (potato or rice), the dark bluish green sclerotia, and the buff sporodochia. As was to be expected, contaminations were sometimes present, and other Fusaria than *F. oxysporum* developed occasionally. Sometimes the difficulty in obtaining a "high culture" (Appel and Wollenweber 2, p. 22) of the Fusarium rendered identification somewhat less certain, owing to the paucity of macroconidia produced, or to the suppression of some other distinguishing character. The cultures were, however, run along with authentic *F. oxysporum* obtained originally from Wollenweber's laboratory (Nos. 3315 and 3394) through the courtesy of Dr. W. A. Orton. Specimens were also submitted to Dr. C. D. Sherbakoff for identification.

Ordinary wilt of potato in Minnesota appears, then, to be due, at least predominantly, to *Fusarium oxysporum.* This fungus has also been isolated several times from tubers showing brown ring discoloration. It was thus obtained from tubers grown as far north as Kittson County, in the extreme northwestern corner of the state.

ETIOLOGY OF FOOT ROT

Isolations were made from numerous wilted plants showing atypical wilt symptoms in the expectation that organisms other than *F. oxysporum* were the causal agents. Some isolations obtained by A. G. Tolaas from atypically affected plants in 1914 and 1915 were identified by the writer. The fungus obtained from plants showing foot rot symptoms was found in the majority of cases to be *F. oxysporum* and, as already indicated, the unusual appearance is attributed particularly to the heavier precipitation resulting in a watersoaked condition of the soil. This is most likely to occur in a heavy soil such as that in the Red River Valley. Other fungi and several bacteria were also isolated, but all the evidence indicated that they were merely saprophytes.

OCCURRENCE OF *FUSARIUM OXYSPORUM* IN POTATO PLANTS

In the course of development of the wilt or foot rot disease, considerable amounts of the infecting fungus are of course accumulated in the tissues of the potato stems, roots, stolons, and even in the tubers.

The following observations indicate that the fungus may grow on other parts of the plant also, and develop in greater abundance on those parts mentioned.

On vines affected with wilt in the field and placed two or more days in a moist place, a luxuriant growth of fungus may develop. (See Figure 4.) From the surface and the interior of these vines, *F. oxysporum* was isolated. Not infrequently the mycelium and spores of *F. oxysporum* may have developed abundantly in the somewhat hollow areas within the stem of plants affected in the field. Plants affected with wilt or foot rot may thus cause heavy contamination of the soil.

Isolations were made on September 10, 1917, to determine if *F. oxysporum* might be present more or less saprophytically in the stems of plants late in the season. This was shortly after a frost had practically destroyed the leaves. These plants had been grown at University Farm, part of them from northern grown seed, had not shown signs of wilt, and had produced a good crop of healthy tubers. Below the surface of the soil the inside of these stems was browned, and from some such stems "high cultures" of *F. oxysporum* were readily obtained. Similar isolations were made later in 1917, and several on October 1 and 2, 1918. The isolations made in 1918 were from the old stems of normal plants which had been killed by frost. They were taken from a field in Hennepin County which had been sprayed with bordeaux mixture, and which had yielded 214 bushels per acre. *F. oxysporum* was obtained consistently from this material.

The "dry stem rot" of potatoes with which Rhizoctonia is associated is common in Minnesota. That *Fusarium oxysporum* may occasionally be a factor in causing this condition is indicated by the fact that it was isolated from the external stem lesions of plants affected with "stem rot," as well as from the interior of such stems. The interior of potato stems affected with dry stem rot is often browned, especially near the base. Edson and Shapovalov (15) have shown recently that various fungi, including *F. oxysporum*, may cause stem lesions. Rhizoctonia hyphae may of course be present even if they are not the primary cause of the lesions.

The seed piece under the growing plant is often rotted. If the rot is caused by bacteria it is soft and foul smelling. Species of Fusarium may cause a dry rot. The rot of the seed piece may be soft and without a foul odor. Isolations were made in the season of 1917 from several such cases as the last two. The specimens were obtained from University Farm and other parts of the state. *F. oxysporum* was often obtained from seed tubers affected with soft rot. From tubers affected with dry rot, *F. discolor sulphureum* (Schl.) App.

and Wr. and other Fusaria were obtained. Bacteria and other fungi were of course commonly present as secondary organisms. No difficulty was experienced in securing a more or less soft rot of potato tubers with *F. oxysporum* by artificial inoculation.

Considerable mycelium of *F. oxysporum* may occur in and on the leaves of plants growing under moist conditions, even when the lower stem does not show the presence of the fungus. Such leaf infection may presumably result from inoculum carried by insects or spattered by rain. Milbrath (37) reports that leaves may be affected, altho he may have meant only internally. (See also 15.) Cases of external as well as internal infection of leaves and petioles have been secured from artificial infection in the greenhouse.

The relation of *F. oxysporum* to the soil is discussed in another section.

ARTIFICIAL INOCULATIONS WITH F. OXYSPORUM ON POTATO PLANTS

Many preliminary experiments in the greenhouse and in the field to secure infection and wilt of potato plants by artificially inoculating *F. oxysporum* into the seed piece planted, or into the soil, were unsuccessful. An examination of the literature indicates also that other workers have not had great success in securing infection of potato plants with the wilt organism under ordinary conditions. It is evident that *F. oxysporum* is not vigorously parasitic to actively growing potato plants.

Sometimes such results as shown in Figure 6 were obtained under greenhouse conditions. Rotting of the seed piece, browning of the stem, and death of the leaves ensued from inoculating the seed tuber with *F. oxysporum*. This is hardly characteristic of Fusarium wilt, however, tho resembling the foot rot condition.

In view of the possibility that the average temperature in the greenhouse during the winter months was not sufficiently high for good infection, the cage shown in Figure 7 was constructed, and heated with two carbon electric light bulbs. A soil temperature of from 20 to 30 degrees could thus be maintained. The humidity was of course also high. Figures 8 and 9 show a type of injury resulting from inoculating sterilized soil heavily with *F. oxysporum* under these warm and damp conditions. This injury was caused several times with *F. oxysporum*, and *F. radicicola* Wollenw. caused a similar injury in one trial. Fitch and Bennett (17) illustrate a somewhat similar condition as found in the field. Link (33) also secured stem rots in the laboratory with *F. oxysporum*. Injuries such as are illustrated in Figures 8 and 9 are considered entirely comparable with the naturally occurring foot rot condition illustrated in Figures 3 and 4.

Figures 10 and 11 show two infected plants resulting from a lighter infection of the soil, and are believed to represent a fair greenhouse manifestation of Fusarium wilt. It is to be noted that the upper leaves show the characteristic rolling (see 1, p. 143). The higher temperatures in the warm chamber, while allowing infection, were unfavorable to the potato. Plants placed inside the chamber died sooner than corresponding plants left outside.

FIELD STUDIES WITH SEED TUBERS FROM WILTED PLANTS

Wilted plants do not result from planting infected seed, unless conditions are favorable to the development of the fungus. These conditions, particularly a high temperature, are often at the same time unfavorable to the potato. Seed from vines wilted in the field, showing more or less of the bundle blackening, usually produced plants in the greenhouse similar to those from normal seed. Such seed planted in the field in 1917 in not seriously infected soil gave no more wilt than several plots from ordinary seed.

A fairly extensive study of the effect of planting tubers produced under wilted vines was made in the field in 1918. Late in the summer of 1917 several Green Mountain potatoes were dug by hand from under badly wilted vines in Clay County, Minnesota. There was no marked amount of stem end discoloration of the tubers at digging time, nor did this vascular browning increase appreciably through the winter. Through the courtesy of Dr. G. H. Coons, a half bushel of tubers was obtained in the spring of 1918 from a field in Michigan which had shown from 30 to 40 per cent of wilt. Plantings were made in the field at University Farm. The tubers from Clay County were planted whole, and those from Michigan were divided into two lots. Several isolations were made from one lot to determine the fungi present in the browned vascular tissue of the stem end of the tubers. *F. oxysporum* and various other Fusaria were obtained. The other lot was used for planting, and the tubers were sorted into two groups according to size. The smaller tubers were halved to give eye and stem ends, and the larger tubers were cut longitudinally through the former point of attachment of the stolon, then cut transversely, to give two each of approximately equal eye ends and stem ends. These were planted in two places on University Farm. The stand of the potatoes obtained from Michigan was poor, owing particularly to frost necrosis of the tubers (29) and to the fact that the "seed" had been obtained from seriously affected plants. It was also necessary to plant the tubers rather late in the spring. The seed pieces were planted 16½ inches apart in rows 3 feet apart.

The average yield of the tubers from Clay County was slightly more than one pound per hill (29½ pounds from 25 hills) or at the rate of 180 bushels per acre. The plants were not wilted. The yield indicates that the seed was not affected; indeed, it is possible that the greater immaturity of such seed resulted in added vigor of the progeny.

The results with the seed from Michigan are summarized in Table II.

TABLE II

RESULT OF PLANTING TUBERS FROM BADLY WILTED VINES

Character of seed piece	Date planted	Area of plot*	No. of wilted plants	Yield	Rate per acre
		Sq. Ft.		Pounds	Bushels
Eye quarters	June 4	268.5	0	32.0	86.5
Stem quarters	June 4	268.5	2	23.0	62.2
Eye halves	June 4	148.5	2	12.0	58.4
Stem halves	June 4	148.5	1	14.5	70.9

* Including proper marginal area about plot.

In 1918 a plot of the eight standard varieties (6) was planted, and a considerable amount of fungus from cultures of *F. oxysporum* introduced into the soil beside each seed piece at planting time. Here again only healthy plants were produced, indicating that none of the varieties is particularly susceptible to the fungus, unless other factors are conducive to the development of wilt.

The data presented in Table II indicate that serious disease does not necessarily follow from planting seed from wilted vines, and that no more wilt may result from the use of the stem ends than from the use of eye ends. Other observations support this view. Wilted plants do not, of course, produce tubers of as good quality as healthy plants, and it can not be denied that infected tubers may introduce more of the disease into the soil. Such seed is considerably less desirable than seed from healthy plants, and plants affected with wilt should be rogued from plots to be dug for seed. Selecting seed or clipping the stem ends is, however, not alone sufficient to avoid loss from wilt. The considerations involved in the use of affected seed from the north for planting in the southern states require further attention.

FUSARIUM DRY ROT OF POTATO TUBERS

HISTORICAL

Some of the earlier literature regarding Fusarium rots of potato, both American and European, is summarized by Smith and Swingle (63) and in part by Manns (36), altho these authors did not distinguish between the Fusaria causing dry rot and those causing wilt.

The monograph by Appel and Wollenweber (2) made it possible to distinguish between species of Fusaria. Jamieson and Wollenweber (25) reported *F. coeruleum* (Lib.) Sacc. and *F. discolor sulphureum* to occur in Germany as wound parasites, and the American *F. trichothecioides* Wollenw. was described and reported from Washington, Minnesota, Iowa, Nebraska, and South Dakota. Inoculation studies were described. *F. tuberivorum* Wilcox and Link (75) was considered a synonym of the previously established *F. trichothecioides.* Orton (41) in 1913 gave a brief description of this "powdery dry rot" and suggested methods of control. Wollenweber (76) distinguished sharply between wilt- and rot-producing Fusaria. Carpenter (8), besides showing that this sharp distinction did not hold for tuber rots, described *F. eumartii* as a new species of Fusarium causing dry and wet rot of tubers. He also reported *F. radicicola* as producing tuber rot through wound infection. Pratt (49, 51, 52) showed that *F. radicicola* and *F. trichothecioides* were apparently well distributed through the western desert soils, and suggested disinfecting the stock before storage or the use of cold storage, as a control measure against rot. Link (33) has shown that *F. trichothecioides* can cause wilt as well as rot, and also that *F. oxysporum* can cause rot as well as wilt. Sherbakoff (59) stated that the Fusarium most commonly producing potato rot in the eastern United States is *F. coeruleum.* Pethybridge (46, 47, 48), in Ireland, performed experiments with dry rot of potatoes which he considered due to *F. coeruleum.* Orton (39) and Haskell (20) have found that *F. eumartii* can cause, besides a tuber rot, a wilt or stem rot of the potato plant. Milbrath (37) reported dry rot to be serious in North Dakota, causing a loss of "over 20 per cent in all storehouses in the Northwest" in 1914. Altho he did not specify which Fusarium was responsible, it is noteworthy that Carpenter mentions having isolated *F. discolor sulphureum* from tubers sent in by Milbrath, as well as from tubers obtained from South Dakota. Other references to *F. discolor sulphureum* (2, 25, 59, 76) mention its presence in Germany, and nowhere has the writer seen it referred to as being serious in the United States.

DISTRIBUTION

In the United States, Fusarium dry rots appear to be widely distributed east and west, but the north central part of the country has not been very critically surveyed. In Minnesota, isolations have been made from tubers grown in Kittson, Pennington, Polk, Norman, Mahnomen, Clay, Wilkin, Otter Tail, Bigstone, Swift, and Lincoln counties, along the western side of Minnesota, and from Brookings County, South Dakota. Some have also been made from the region of the Twin Cities and from Crow Wing and Kanabec counties.

SYMPTOMOLOGY

The Fusarium dry rot of potatoes found in Minnesota is a brown, compact, firm rot, without the foul odor of bacterial rots. Cavities are often present in the tissues. These cavities and the tissues contain considerable mycelium which develops readily and abundantly when the tuber is placed in a damp chamber. From the edges of the rotted areas, pure cultures of the fungus may usually be obtained directly from tissue cultures. The skin of the potato is often wrinkled. Figures 12, 13, and 14 show the appearance of this rot as found in storage. The rot starts at any point on the potato, and in the case of stored potatoes usually from a wound. It is more abundant as the winter advances. It does not have the powdery appearance characteristic of the rot caused by *F. trichothecioides,* because the spore masses when present are more compact and less dry.

Sections of rotted potato show that the fungus grows through the cells in considerable abundance. The observation of Orton (39) and Pratt (49) that a dry rot fungus has a tendency to follow the vascular system can be confirmed in tubers rotted by *F. discolor sulphureum.* The writer's experience in general corroborates Carpenter's observations (8) that there is no real distinction between the effects of Fusaria causing dry and soft rots, altho *F. discolor sulphureum* under ordinary conditions produces a dry rot.

ETIOLOGY

F. discolor sulphureum was obtained readily from affected tubers grown in many parts of Minnesota. Altho the fact that this Fusarium is the cause of a dry rot of potatoes has not been emphasized, it is one of the most common causes of rot in Minnesota, particularly in the Red River Valley. The ability of this fungus to cause dry rot has been demonstrated frequently.

EXPERIMENTAL

Efforts to determine varietal differences in susceptibility were unsuccessful. The eight standard varieties for Minnesota (Brown and Wellington, 6) were used, and rot developed from wound inoculations in each variety.

A series of experiments was made to determine the relations of injury to the tuber and of moisture and temperature to the development of the rot caused by *F. discolor sulphureum.* Tubers were inoculated on the uninjured epidermis, on the surface after slight wounding with a sterile scalpel, and in deeper cuts into the tuber. Sets of inoculated tubers were kept at different temperatures under damp conditions, and similar sets in dessicators containing calcium chloride. The results are summarized in Table III. (See Figure 15.) The extent and rapidity of the rot is proportional to the seriousness of the injury to the tuber, tho the fungus may sometimes enter through uninjured surfaces, probably through lenticels. The later series of inoculations (December, 1918), incubated for 13 days (see Table III), resulted in less infection than in the previous experiments. A less vigorous "strain" of the Fusarium may have been used. There are characteristic differences in the rot developed at different temperatures. Under cooler conditions, the tissues are darkened and contain few "pockets" and few spores. It is evident that the fungus can rot tubers readily under dry conditions, especially if it gains entrance through wounds. The absence of wounds appears to retard the development of *F. discolor sulphureum* more than dryness or storage temperature, except in the case of cold storage.

TABLE III

EFFECT OF INJURY, TEMPERATURE, AND MOISTURE UPON THE OCCURRENCE OF THE ROT OF POTATOES CAUSED BY *F. discolor sulphureum*

Character of injury	Moisture	Temperature	Tubers inoculated	Time	Results
		Degrees		Days	
None	Saturated	1.1–1.7	4	30	No rot
	Saturated	8–10	4	12	No rot
	Saturated	8–10	9	13	No rot
	Dessicator	8–10	4	12	Slight rot in some cases
	Dessicator	8–10	8	13	No rot
	Saturated	Room	4	12	Slight rot in some cases
	Saturated	Room	8	13	No rot
	Dessicator	Room	6	12	Slight rot in some cases
	Room humidity	Room	4	12	Slight rot in some cases
	Saturated	25	6	13	No rot
	Dessicator	25	6	13	No rot
Slight	Saturated	1.1–1.7	4	30	Trace rot
	Saturated	8–10	4	12	Moderate rot on all
	Saturated	8–10	9	13	Slight rot on 3 tubers
	Dessicator	8–10	4	12	Moderate rot on all
	Dessicator	8–10	8	13	Slight rot on 4 tubers
	Dessicator	Room	6	12	Moderate rot on 4 tubers
	Saturated	Room	4	12	Moderate rot on all
	Saturated	Room	8	13	Slight rot on 2 tubers
	Saturated	25	6	13	Slight rot on 2 tubers
	Dessicator	25	6	13	Slight rot on 3 tubers
Considerable	Saturated	1.1–1.7	8	30	Slight rot
	Saturated	8–10	6	12	Much rot on all
	Dessicator	8–10	6	12	Moderate rot on all
	Dessicator	Room	4	12	Much rot on all
	Saturated	Room	4	12	Much rot on all
	Room humidity	Room	4	12	Much rot on all
	Saturated	25	5	12	Much rot

Pethybridge (47) has reported that young-sprouts of uninjured tubers may be killed by heavy inoculations with *F. coeruleum*. *F. discolor sulphureum* likewise injures young sprouts if present in abundance.

Sherbakoff (59) and Pethybridge (47) have found that potato tubers rot more readily after sprouting. To determine the relative susceptibility to rot of old and new potatoes, several inoculations were made October 16, 1917, on recently harvested tubers and on tubers of the 1916 crop kept in cold storage for more than a year. The latter had sprouts only about fifteen millimeters long at the beginning of the experiment. At room temperature under a bell jar, the tubers grown in 1916 showed, October 26, about twice as large an area of rot as did those of the 1917 crop. The difference was due partly to greater shrinkage of tissue in the older potatoes. Nevertheless the newer potatoes had developed a considerable amount of rot. Additional tests with sprouted and non-sprouted tubers grown the same year indicated that while sprouted tubers usually rotted more extensively, sprouting was not at all a controlling factor in the development of the rot. In sprouted tubers there is a marked shrinkage of the tissue. Naturally infected tubers frequently rotted before the appearance of any sprouts.

Experiments to determine the effect of the fungus on tubers showing frost necrosis (Jones and Bailey, 29) as compared with healthy tubers, were made by inoculating, at the same time, both kinds of tubers. These experiments failed to show that the injury by frost had increased susceptibility to rot. Likewise, it was found that the tubers from "constitutionally degenerate" plants which had shown the so-called curly dwarf symptoms were no more susceptible to the rot caused by *F. discolor sulphureum* than were normal tubers. Indeed, the degenerate tubers often showed smaller rotted areas than did the healthy tubers.

No characteristic wilting of the foliage resulted on potato plants grown from tubers infected with *F. discolor sulphureum*. Several trials for the purpose of determining the effect of planting diseased tubers under field and greenhouse conditions gave the following results:

1. If the tuber or seed piece were badly affected at planting time, the continued rotting frequently resulted in the destruction of the sprout. Sometimes this destruction of the seed piece and the sprout ensued even when only a small amount of rot was present at planting time.

2. If the sprout were well started before the seed piece was completely rotted, it usually continued to grow, altho the resulting plant was unthrifty, owing to the loss of the reserve food in the seed piece,

and also perhaps in part to the presence of "toxic substances" (see below) in the rotting tissue in contact with the base of the sprout.

3. The rot might not develop rapidly enough to affect the sprout or growing plant. (Figures 16, 17, and 18 show examples of cases 2 and 3.)

Fusarium trichothecioides Wollenw. has been reported from St. Paul (25, 8). The writer is uncertain as to whether the tubers referred to were grown in St. Paul or collected there. At any rate, he has never isolated *F. trichothecioides* from a potato grown in Minnesota. This, of course, does not mean that it does not occur, since the whole state has not as yet been thoroly surveyed for tuber rots, but this Fusarium is apparently not abundant. It has been isolated several times from potatoes shipped in from western points, including one lot from North Dakota.

FUSARIUM DISEASES OF CERTAIN TRUCK CROPS

Fusarium injuries may be of considerable importance to various truck crops in the United States (71), even tho a definite wilt is not produced. Root rots and stem injuries due to Fusaria are rather common on several crops. Members of the Leguminosae (see 60) such as cowpea, pigeon pea, and soybean, are seriously affected.

WILT AND ROOT ROTS OF *PISUM SATIVUM*

Fusarium vasinfectum pisi was established by Van Hall (73) as the cause of St. John's disease of the garden pea. The Fusarium which Schikorra (60) assigned to the same species was determined by Appel and Wollenweber (2) to be identical with their species *F. falcatum,* which was reported to occur on garden peas in Germany, and on tomato fruit in Germany and the United States (76, 59). Lewis (32) isolated a Fusarium from diseased *Pisum sativum* in Maine, which Wollenweber determined as *F. orthoceras* App. and Wr. Wollenweber (76) also described a new species, *F. redolens,* with the following notes: "Vascular parasite, cause of wilt and foot disease of *Pisum sativum.* Distribution unknown." This author also considered that "More than one species, differing both in size of conidia and color of conidial masses, may cause the St. John's disease of the garden pea."

Little information is as yet at hand regarding the distribution or seriousness of Fusaria affecting the garden pea in the United States.

The first report of a serious outbreak of this disease in Minnesota came in late June, 1916, from Le Sueur. The disease caused considerable damage in a field of about 16 acres. A wilt of garden peas was reported from near Kasson in 1917.

Species of Fusarium have been found (4) associated with the diseased condition of roots and stems of the garden pea in Minnesota. One species, evidently belonging taxonomically in the section Martiella Wollenw. (76) has been found to be particularly pathogenic. The stem and root injuries resulting in wilt of the pea plants have been obtained from infecting the soil or sterilized seeds when planted in either sterilized or unsterilized soil. If considerable inoculum be applied, the seeds may rot before sprouting or shortly after (Figure 19). With a less heavy infection the plants may grow to a considerable size before the general rotting of the roots and lower stem results in wilting and death.

Studies of this disease are being made by Dr. F. R. Jones, of the United States Department of Agriculture, with whom the writer is coöperating. Cultures of the Fusarium have been submitted to Dr. Sherbakoff for taxonomic consideration. The writer has used this Fusarium in some comparative studies with other Fusaria, as reported later in this paper.

ROOT ROTS OF THE BEAN (*PHASEOLUS VULGARIS*)

Burkholder (7) reported Fusarium root rots of the bean to be serious in New York State. Reddick (55) reported that Burkholder found the fungus to be similar morphologically to *F. martii*, but different physiologically; he called the fungus *Fusarium martii phaseoli*, and described experiments indicating important relations between temperature and the development of bean plants and the "hemi parasite." Several pathologists have reported (71, p. 8) troubles from root rots due probably to Fusarium, from various sections of the United States.

Rots of the roots and lower stem of bean plants have been noted in Minnesota, particularly in the spring while the plants are still small and the ground cool. From such injured roots a Fusarium was isolated. Inoculation experiments demonstrated the pathogenicity of this fungus to bean plants. This Fusarium has been utilized in some temperature studies, as noted under a subsequent heading. Upon submission of the fungus to Dr. Burkholder, he pronounced it to be probably different from his *F. martii phaseoli*.

FUSARIUM DISEASES OF OTHER TRUCK CROPS IN MINNESOTA

Muskmelon wilt.—A Fusarium was isolated by G. R. Hoerner, of the Section of Plant Pathology, in 1916, from wilted muskmelon vines. The fungus has not been found to agree with either *F. niveum* E. F. Smith or *F. vasinfectum* Atk. (see 61, 71, 72). Inoculation experiments did not demonstrate that it was particularly parasitic to muskmelons or cucumbers. In 1918, two reports of non-bacterial wilt were received from the region of the Twin Cities, and from one field Fusaria somewhat similar to the one isolated in 1916 were obtained. The trouble did not become serious in the field in 1918, and the writer considers the Fusaria to have been present semi-parasitically, gaining entrance when the plants were in a nonvigorous condition.

Rots of vegetables.—Fusaria causing rots of cucumber fruits have been isolated, and are not uncommon, affecting either green or ripe cucumbers. In view of the inoculation experiments reported later, the writer regards these Fusaria as acting semi-parasitically, not as specific parasites restricted to the cucumber. Lewis (32) obtained rots of cucumber fruits with several different Fusaria.

Wollenweber (76) has described *Fusarium sclerotium* as causing a rot of tomato fruits, and has found that *F. falcatum* also causes a rot of tomatoes. He named a fungus obtained by Lewis (32) from tomato fruits, *F. citrinum.* The writer also has isolated Fusaria from the tomato fruit. A wilt of tomato such as is caused by *F. lycopersici* Sacc. in the south and *F. oxysporum* and *F. orthoceras* App. and Wr. in the west (24) has not been definitely found in Minnesota.

Rots of carrot and other vegetables due to various Fusaria are quite common, particularly in storage and following wounds. The rots may be soft or dry. No specificity appears to exist between these fungi causing various fruit and vegetable rots and the hosts on which they may be found. This is also indicated by the inoculation experiments recorded later.

Fusarium ear rots of corn (*Zea mays*).—Pammel, King, and Seal (44) have summarized the literature of Fusarium diseases of corn. They found that roots, stalks, and ears were attacked, but the Fusaria isolated were not named. Sheldon (58) described *Fusarium moniliforme* as the cause of moldy corn. Hoffer and Holbert (22) have recently called attention to injury to corn plants by Fusaria and bacteria.

The symptoms considered by the writer have been particularly rots of the ear and cob, ordinarily pinkish or reddish in color. Such rots were widely distributed in Minnesota in 1917. As a result of early frosts that year, much immature corn was gathered.

Fusaria were isolated from field corn in the crib, but more particularly from sweet corn in the field. While inoculations have not been made to determine the pathogenicity, it was soon suggested from laboratory studies in 1917 that the Fusarium from some isolations from corn (both sweet and field varieties) were identical morphologically with *F. culmorum* (W. Sm.) Sacc., the wheat scab organism. Hoffer has been working upon this problem, and with others has published (23) results of cross-inoculations.

EFFECT OF TEMPERATURE ON VARIOUS FUSARIA

The relations of temperatures affecting the development of host and parasite are highly important. Considering Fusaria, the work of Humphrey (24), Link (33), Tisdale (69), Gilman (18), and others is summarized by Jones (28). The papers of Reddick (55) and of Wollenweber (76) also deal with this question.

Several of these authors have emphasized the fact that infection by the Fusarium is more serious at, or even dependent upon, a temperature near the optimum for the fungus; in the case of flax wilt, there appears to be a definite temperature below which the plant is not affected (Tisdale, l.c.). The suggestion of Reddick (l.c.) that the fungus may develop upon the host when unfavorable temperature has lowered its vitality, is important and has perhaps been partially overlooked.

Several experiments were begun in 1917 to test the relation of certain Fusaria to temperature. While the relation of the host plants to the different temperatures was not critically determined, considerable is already known in a general way.

The low temperature used in the experiment (1.1 to 1.7 degrees C.) was practically constant. The temperatures of 25, 30, and 35 degrees were fairly constant. The medium used of course strongly affects the rate of growth of the fungus. In these experiments, potato dextrose agar was employed, and since the four Fusaria were subjected in each case to the same conditions, the data are comparable at each of the different temperatures. More than one set of cultures was run at most temperatures, and from three to eight measurements were made at different periods of time. A partial series run later and not included in the table gave figures somewhat different, tho a similar relation existed between the rates of growth of the four Fusaria at each of the temperatures utilized.

Analysis of Table IV shows that the Fusarium from the bean can make a good growth at 1.1 to 1.7 degrees C., and at temperatures of 20 degrees and below grows somewhat more rapidly than does the Fusarium from pea, while at 25 degrees and above the reverse is true. The growth of each Fusarium is comparatively more favorable at the temperature more unfavorable for its host. This supplements Reddick's (55) observations. *F. oxysporum* grows well at temperatures unfavorable for the potato plant. *F. discolor sulphureum* makes but slight growth at 1.1 to 1.7 degrees, but is able to cause a slight amount of rot at this temperature (see Figure 20). At 8 to 10 degrees, this fungus rots tubers readily as shown in Figure 21.

TABLE IV

THE EFFECT OF TEMPERATURE ON THE RATE AND CHARACTER OF GROWTH OF FUSARIA

Temperature	Fusarium	Av. daily growth in radius	No. days measured	Character of mycelium	Macroconidia or sporodochia
Degrees, C.		mm.			
1.1–1.7	From bean	1.4	14	Loose aerial	No sporodochia
	From pea	None	14	....	....
	F. oxysporum	None	14	....	....
	F. discolor sulphureum	Trace	14	....	....
8–10	From bean	2.4	13 to 20	Loose aerial	No sporodochia
	From pea	2.0	13 to 20	Close to med.	Few macroconidia
	F. oxysporum	1.7	13 to 20	Thickset aerial	No sporodochia
	F. discolor sulphureum	3.4	13 to 20	Loose aerial	No sporodochia
14–16	From bean	4.5	6 to 13	Loose aerial	No sporodochia
	From pea	4.2	6 to 13	Close to med.	No sporodochia
	F. oxysporum	4.5	6 to 13	Loose aerial	No sporodochia
	F. discolor sulphureum	6.6	6 to 13	Loose aerial	Some macroconidia
Room temperature	From bean	6.6	4 to 6	Loose aerial	No sporodochia
	From pea	9.0	4 to 6	Close to med.	Few sporodochia
	F. oxysporum	12.0	4 to 6	Loose aerial	Few macroconidia
	F. discolor sulphureum	13.0	4 to 7	Close to med.	Many sporodochia
25	From bean	6.6	4 to 6	Loose aerial	Some sporodochia
	From pea	9.0	4 to 6	Rather loose	Some sporodochia
	F. oxysporum	12.0	4 to 6	Loose aerial	Few sporodochia
	F. discolor sulphureum	13.0	4 to 6	Close to med.	Pseudopionnotes
30–31	From bean	4.7	4 to 6	Loose aerial	No sporodochia
	From pea	9.5	4 to 6	Rather loose	No sporodochia
	F. oxysporum	9.6	4 to 6	Rather close	Few macroconidia
	F. discolor sulphureum	6.0	4 to 6	Very close	Abundant pseudopionnotes
35–36	From bean	Trace	8	....	....
	From pea	4.3	8	Loose	No sporodochia
	F. oxysporum	3.2	8	Close to med.	No sporodochia
	F. discolor sulphureum	Trace	8	....	....

From about 8 to 15 degrees C., *F. discolor sulphureum* develops a loose vegetative mass of mycelium without sporodochia, whereas at about 20 degrees and above macroconidia are produced, more abundantly as the temperature rises, until at 30 degrees a dense pseudopionnotes is produced, with mycelium close to or sunken in the agar. Removal of cultures of this fungus from higher or lower temperatures to room temperature allows again the development of the growth characteristic in the new temperature. (Figures 22 and 27.) The abundant spore production of this fungus at higher temperatures has a bearing on the accumulation of inoculum in storage houses, and perhaps fields, during the summer months.

Freezing would hardly be expected to injure Fusaria. Bartram (3) reported, however, that a Fusarium obtained from conifers succumbed to temperatures occurring in winter at Burlington, Vermont. Cultures of *F. oxysporum* exposed to the outside temperature from December 21, 1917, to February 11, 1918, began growing again when brought indoors, and transfers developed normally. This exposure not only involved at times temperatures far below freezing, but, since the cultures were placed on the south side of the building, exposure to the sun and to alternate freezing and thawing.

Similarly, cultures of *F. discolor sulphureum* were uninjured after exposure out of doors for more than a month during the winter. Wilcox, Link, and Pool (75) found that freezing did not injure *F. trichothecioides*. The frequent observation that Fusaria, and various other fungi as well, can overwinter in the soil shows quite clearly that low temperatures exert no serious deleterious effect upon them.

EFFECT OF MOISTURE, LIGHT, AGE, FOOD

Relations to moisture.—Fusaria grow readily in culture both on rather dry substances such as clover stems, and when submerged in liquid media. Possible oxygen relations involved have not been tested by the writer. That these fungi withstand dry conditions well is indicated by the fact that more than a year after inoculation test tube agar cultures of *F. oxysporum* were still viable; *F. trichothecioides* was still viable after 25 months. The tubes were exposed all this time to the dry and often warm conditions of the laboratory. Humphrey (24, p. 15) reports viability of cultures containing chlamydospores after two years' laboratory dessication in a test tube.

Light.—Cultures grow almost equally well in light or dark, altho, as frequently observed, the colors produced are much more vivid in rather bright light; sunlight on the other hand, is unfavorable.

Age.—That cultures of Fusaria may lose their virulence after some period of time on culture media is suggested as a possibility by Sherbakoff (59) and Link (33). The writer has not found that this necessarily holds true. Cultures of *F. oxysporum* obtained as mentioned from Wollenweber's laboratory on February 8, 1915, and which had of course been isolated some time previously, were still able to cause infection of potato stems and rot of tubers about three years later. Appel and Wollenweber (2) note that cultures were still virulent after two years; Edson and Shapovalov (15) found that age did not lessen pathogenicity. It is of course true that cultures may cease to be "high cultures" and produce fewer macroconidia if transferred, for example, only at long periods. While such cultures may not be as actively virulent as "high cultures," a ready way sometimes to bring about a high culture is by inoculation into the proper host and by subsequent reisolation.

Food.—While the writer has not endeavored to determine specifically which enzymes are produced by certain species of Fusarium, he has grown these fungi on various media, both synthetic and complex; it is obvious that they are not restricted in their saprophytic development as to the food used. The work of Hawkins (21) showed that sucrase, maltase, xylanase, and diastase were secreted by both *F. oxysporum* and *F. radicicola.* He found these two fungi to have practically the same effect on the potato.

The situation with regard to the use of starch by various Fusaria requires special consideration. Smith and Swingle (63) noted that the starch grains in a rotted potato (causative Fusarium not certainly *F. oxysporum*) were not corroded, altho they found some change as evidenced by the staining reaction with iodine. Hawkins (l.c.) observed that starch was not used by the Fusaria with which he worked unless first gelatinized. Hawkins sought an explanation in the slowness of action or diffusibility of the enzyme. It may be noted, however, that many writers consider the outer layer of the starch grain to be not homogeneous with the interior. Shapovalov (56) translates Naumov and Pomasski as finding, however, that *F. roseum* Link and *F. subulatum* App. and Wr., which caused "intoxicating bread," dissolved starch in the seeds of cereals.

The writer has investigated the effect of *F. discolor sulphureum* on starch, with results similar to those reported by Hawkins: starch grains in a rotted potato are intact, and stain as darkly with stronger iodine solutions as grains from normal potatoes. The appearance of less blue (more purplish or reddish) staining with dilute iodine is sometimes to be noted with starch from such rotted potatoes, and is of uncertain significance. On gelatinized starch, that is, starch paste made by boiling starch with distilled water, *F. discolor sulphureum* and several other species of Fusarium grew fairly well and produced normal spores. It would seem, however, that, barring a possibly less ready separation from the tissue, commercial starch should be procurable from dry rotted potatoes.

To test the effect of prolonged action of fungi and bacteria causing rot of potato tubers, a number of tubers seriously affected with *F. discolor sulphureum* were placed on March 1, 1918, in a jar, and this was covered and set away to allow the continued action of the Fusarium as well as any other organisms present. From time to time samples were removed for examination of the starch grains, the mass being then stirred and set aside. The last examination was made December 24, 1918, at which time, after nearly 10 months of "rotting," the mass still contained entirely normal starch grains. Whether the number was reduced can not be stated, but no grains were found showing partial erosion. The rotting of potato tubers does not necessarily affect the starch present. Edson (15a) has recently published in some detail on this point.

CROSS-INOCULATIONS

Table V shows the results of some of the cross-inoculations attempted. The data are not presented unless the lesions produced were fairly definite. The rots reported were all obtained at room temperature. The plants inoculated were kept at a greenhouse temperature of about 18 to 24 degrees C.

The evidence presented in Table V seems to indicate that various Fusaria may cause rot on certain fruits, such as cucumber, apple, or tomato, the host serving as hardly more than a "culture medium," in these cases, for the development of the Fusarium. Potato tubers may also be rotted by several species of Fusarium, altho it was found that with certain Fusaria, rot was obtained more readily after the potatoes had been dug some little time. Sprouting did not seem to be a necessary corollary. Such forms as *F. trichothecioides* and *F. discolor sulphureum,* could of course produce rot at any time. While it is evident that certain forms, including those just noted, are, under natural conditions, the chief producers of injury to potatoes, it is not apparent that any certain species of Fusarium causes rot on tomato, cucumber, and other vegetables.

Cross-inoculation experiments are being continued, since it is evident that the effect of Fusaria on different hosts is important from the standpoint of crop rotation.

TABLE V
RESULTS OF CROSS INOCULATIONS WITH FUSARIA

Fusarium	Host tried	Development	Extent of injury 3 or 4 weeks	Remarks
F. oxysporum	Orange fruit	Rot	¼ fruit	
	Tomato fruit	Rot	½ fruit	
	Potato tuber	Rot	Whole tuber	Usually a soft rot.
	Potato plants	Injury	....	See previous data
	Cucumber fruits	Soft rot	....	
	Apple Fruit	Rot	⅓ fruit	
	Bean plants	No effect noted	....	Sterilized soil used
	Pea plants	Slight root injury		
F. discolor sulphureum	Cucumber fruits	Soft rot	½ fruit	Abundant rot
	Bean plants	No wilt or rot noted	....	Light and heavy inoculations made
	Pea plants	No wilt or rot noted	....	Light and heavy inoculations made
	Potato plants	No "wilt"	....	See previous data
	Potato tuber	Rot, usually dry rot	Whole tuber	See previous data
F. trichothecioides	Orange fruit	Rather soft rot	⅓ fruit	Rind and core particularly attacked
	Lemon fruit	Rather soft rot	¼ fruit	
	Apple fruit	Rather soft rot	½ fruit	
	Sweet potato	Slight rot	25mm	
	Cucumber fruit	Soft rot	⅓ fruit	
	Tomato fruit	Soft rot	⅓ fruit	
	Carrot	Dry rot	¾ carrot	
	Year old potato tuber	Dry rot	½ tuber	
	Newly dug potato	Dry rot	¼ tuber	
	Rotted potato tubers planted	No wilt	....	
F. culmorum	Apple fruit	Slight rot	30 mm	
	Potato tuber	Rather soft rot	....	See previous data and Fig. 21
	Cucumber fruit	Soft rot	¼ fruit	
	Bean plants	No injury noted	....	
	Pea plants	No injury noted	....	
Fusarium from bean	Potato tuber	Rot in some cases	25-40 mm	
	Bean plant	Root rots	....	See previous data
	Pea plant	Slight root injury	....	
Fusarium from pea	Potato tuber	Rot in some cases	25-40 mm	
	Pea plant	Root rots and wilt	....	
	Bean plant	Trace root injury	....	Injury occasional
F. lini	Potato tuber	Some rot	20-40 mm	
	Cucumber fruit	Rot	¼ fruit	
F. lycopersici	Cucumber fruit	Rot	¼ fruit	

DOES THE SUBSTRATUM ALTER THE PATHOGENICITY OF FUSARIA?

Carpenter (8) has reported several Fusaria as able to produce rot in potatoes. Sherbakoff (59, p. 100) noted that "Several series of inoculations of potato tubers showed (a) that a considerable number of Fusaria can cause more or less rapid decay of the tubers, and (b) that most of the Fusaria readily produce rot only after the tubers begin to sprout." Wollenweber (76, p. 37) considered that in general the wilt parasite of one host was not found on living organs of another host, and that "the possibility of the adaptation of the parasite decreases proportionately to the taxonomic distance of the host." He states, however, that "whether such [gradual to other hosts] adaptation occurs and causes changes in the nature of the parasite, indicated in pure culture by differences in general appearance, production of color, etc., has not been determined." Sherbakoff (l. c. p. 103) noted cases of possible mutations or fluctuations and of temporary changes in morphological characters.

Sherbakoff also reported that he had isolated *F. culmorum* from rotted potato both alone and in association with other Fusaria. Wollenweber (l. c. p. 45) stated similarly that *F. rubiginosum* App. and Wr. (a probable synonym of *F. culmorum*) caused rot of potatoes at higher temperatures, but irregularly. The writer has isolated organisms similar morphologically to *F. culmorum* several times from rotted potatoes. In an endeavor to determine whether the morphological or physiological nature of these fungi might be altered by continued development on a host other than their characteristic habitat, inoculations were made with *F. lini*, *F. culmorum*, and the Fusaria mentioned above as pathogenic to peas and to beans. Some rots of potato tubers were secured with all these forms, particularly with *F. culmorum* (see Figures 23 and 24). As yet these Fusaria have not been noticeably changed in morphology or pathology, but experiments should be continued for a much longer time.

THE PRODUCTION OF "TOXIC SUBSTANCES" BY FUSARIA

Lutz (35) has tested the effect of used nutrient solutions, including old Fusarium ("*F. solani*") solutions, upon the germination and development of certain fungi. He found that such fungi produced, after a period of growth upon a medium, substances which retarded the germination or growth of fungi grown subsequently in the same medium, even tho more nutrient substances were added; other fungi produced substances acting as accelerators rather than retarders.

Sometimes both types of substances were produced by the same fungus. The effect of these substances was usually destroyed by boiling, or even by lower temperatures. He was, however, unsuccessful in certain other attempts to demonstrate an enzymatic nature of these substances. Old Fusarium solutions which had been boiled and exposed to the light, allowed in general a larger growth of the fungus subsequently introduced than did the unheated solutions. He found also that for some of his used solutions, filtration through a clay filter removed the accelerating or retarding substances, altho this filtration did not alter the solutions in other instances. Lutz concludes that "Die von bestimmten Pilzen produzierten wachstumshemmenden resp. fördernden Stoffwechselprodukte, welche durch Kochen zerstört werden, haben keine *spezifische Wirkung* in dem Sinne dass sie immer nur auf Keimung und Wachstum derselben Pilzspezies Einfluss hätten; *sie wirken auch auf die Sporen anderer Pilze.*"

On Currie's (14) solution the writer grew *F. oxysporum, F. discolor sulphureum,* the Fusarium injurious to peas, *Rhizopus nigricans,* and other fungi. After the fungi grew for different periods of time, these solutions were filtered carefully through filter paper, since a clay filter may, according to Lutz, absorb the products in question. The results of preliminary germination tests made with spores of *F. oxysporum* and *F. discolor sulphureum,* agreed in general with Lutz's results, and indicated that substances were produced by these fungi which were inhibitory to the subsequent germination and early development of the two Fusaria in the same solution. Boiling the solutions destroyed this inhibitory action.

Coons (13) reported work showing that *F. oxysporum* produced substances filterable through a Berkefeld filter, which caused early wilting of cuttings from potato vines when immersed in the filtered solution. Lathrop (31) found aldehydes to be produced by *F. cubense* E. F. Sm. Peltier (45) determined that a Botrytis produced a "harmful substance" that "may be some inorganic acid other than oxalic, or it may be a toxin of some kind, which, however, is not destroyed by heating to 100 degrees C." Graves (19) found that *Rhizopus nigricans* produced substances that exerted a negatively chemotropic effect upon the fungus greater than the positive chemotropic effect of certain food materials.

The solutions mentioned above, on which the Fusaria and Rhizopus had grown in Erlenmeyer flasks closed with cotton plugs for different lengths of time, were filtered, and leaves of potato, coleus, ragweed, and other plants, all cut off under water, were introduced (Table VI).

TABLE VI

EFFECTS OF SOLUTIONS IN WHICH FUNGI HAD GROWN, ON THE WILTING OF EXCISED LEAVES

Fungus which had grown in the solution	Time of growth in solution	Treatment of solution after filtration	Plant from which leaves were taken	Approximate time before consp. wilting
				Hours
F. oxysporum	2 months	None	Potato	2[*]
F. oxysporum	2 months	Boiled	Potato	2
F. oxysporum	2 months	Diluted half with water	Potato	4
F. oxysporum	2 months	Diluted and boiled	Potato	4
F. oxysporum	2 months	None	Coleus	12
F. oxysporum	10 days	None	Potato	24[†]
F. oxysporum	10 days	None	Lamb's quarters	4[†]
F. oxysporum	42 days	None	Potato	7
F. oxysporum	42 days	Diluted half with water	Potato	8
F. oxysporum	42 days	Filtered through diatomaceous earth	Potato	10
F. oxysporum	42 days	None	Ragweed	7
F. oxysporum	42 days	Diluted half with water	Ragweed	7
F. oxysporum	42 days	Filtered through diatomaceous earth	Ragweed	8
F. discolor sulphureum	2 months	None	Potato	2
F. discolor sulphureum	2 months	Boiled	Potato	2
F. discolor sulphureum	42 days	None	Potato	7
F. discolor sulphureum	42 days	Boiled	Potato	8
F. discolor sulphureum	42 days	None	Ragweed	6
F. discolor sulphureum	42 days	Boiled	Ragweed	6
Fusarium from pea	2 months	None	Potato	3
Fusarium from pea	2 months	None	Coleus	12
Fusarium from pea	2 months	Diluted half with water and neutralized	Potato	4
Fusarium from pea	2 months	Diluted as above and boiled	Potato	4
Fusarium from pea	2 months	Diluted with 3 vols. water and neutralized	Potato	4
Fusarium from pea	2 months	Diluted as above and boiled	Potato	4
Fusarium from pea	42 days	None	Potato	7
Fusarium from pea	42 days	Made slightly alkaline	Potato	7[‡]
Fusarium from pea	42 days	Diluted with 3 vols. water	Potato	8
Fusarium from pea	42 days	Boiled	Potato	7
Fusarium from pea	42 days	None	Ragweed	4
Fusarium from pea	42 days	Made slightly alkaline	Ragweed	4
Fusarium from pea	42 days	Diluted with 3 vols. water	Ragweed	5
Fusarium from pea	42 days	Boiled	Ragweed	3
Rhizopus nigricans	2 months	None	Potato	1½
Rhizopus nigricans	2 months	None	Coleus	5
Rhizopus nigricans	42 days	None	Potato	7
Rhizopus nigricans	42 days	Boiled	Potato	6
Rhizopus nigricans	42 days	Boiled	Ragweed	6
Rhizopus nigricans	42 days	None	Ragweed	6
None	None	Curries, freshly made	Potato	24+
None	None	Curries, freshly made, boiled	Potato	24+
None	None	Curries, 42 days old	Potato	16
None	None	Curries, 42 days old	Ragweed	10
None	None	Curries, 42 days old, boiled	Potato	14
None	None	Curries, 42 days old, boiled	Ragweed	10
None	None	Tap or distilled water	Potato	48+
None	None	Tap or distilled water	Coleus	48+
None	None	Tap or distilled water	Ragweed	24+

[*] Potato leaves for tests at any one time were taken from plants of the same age and in similar condition. For the two-months-old solutions, the leaves were from full-grown potato plants.

[†] Tests after ten days reported in only this case, since with all the solutions it was evident that no particular development of "toxic substance" had ensued.

[‡] Wilt less pronounced than in preceding case.

Tests were also run with other Fusaria, and with Rhizoctonia and Penicillium. Wilting of excised leaves of various plants ensued more rapidly in old solutions. Wilting occurred even after considerable dilution. It is not to be explained on the basis of acidity. It is to be noted that no specific action is evident between the fungi tried and any one plant; potato leaves wilt as readily in old Rhizopus solutions as in solutions in which *F. oxysporum* had grown. This is in agreement with Lutz's results in growing fungi in old solutions. A difference exists, in that boiling the solution exerts no evident effect upon the action of old solutions on the leaves. In certain cases leaves took on a crinkled, distorted, or mosaic appearance, resembling sometimes the condition obtained by Smith (62, pl. 63).

"MIXED CULTURE" RELATIONSHIPS

Nature seldom works with pure cultures. The interrelationships of various organisms forming the mixed cultures of nature have received little study (see Rahn 54, p. 181). In view of the frequency with which various bacteria may be associated with Fusaria in wilt diseases and tuber rots, the writer undertook tests to ascertain some relations between certain bacteria and Fusaria.

It is a matter of common observation that fungi belonging to the genus Fusarium grow vigorously on any of the common culture media. Indeed, Fusaria are often troublesome as saprophytes in isolation, dilution, and other cultures of various organisms, on account of the vigor and rapidity of their growth. The writer has observed Fusaria to grow over and "swamp" colonies of Penicillium and other fungi.

When, for example, two colonies of the same or of different fungi develop in a Petri dish, there is often a mutual cessation of growth at about the point where the colonies meet. Aside from the possible presence of any growth-arresting substance, there may be a lack of food, or possibly some mechanical obstruction of growth from the presence of hyphae, in the case of fungi. With a bacterial and fungous colony, however, the former should offer less mechanical impediment to the growth of the latter.

Rahn (53) and others have shown that bacteria may produce growth-arresting substances, inhibiting more especially the further growth of the same organism. Elliot (16) has emphasized the changes in the mycelial characters of some species of Alternaria due to contact with colonies of certain bacteria. Sherbakoff (59, p. 214 f.) found chlamydospores especially abundant when Fusaria grew in the presence of bacteria.

In the writer's experiments, Petri dishes of potato dextrose agar were used, inoculated at the center with the Fusarium, and midway on the radii with bacteria at the same time, then incubated until the colonies reached each other. In other cases the bacteria were first inoculated in the center and, since the Fusaria usually grow more rapidly than the bacteria, after incubation from one day to three days the Fusaria were inoculated on the radii. *F. oxysporum, F. discolor sulphureum,* and the Fusaria from the bean and the pea were employed. *Bacillus atrosepticus* v. Hall, obtained through the courtesy of Dr. Morse, was used, since the blackleg organism is often found in both the stems and the tubers of potatoes. *B. carotovorus* Jones, certain undetermined species of bacteria isolated from rotted potato tubers and stems, *Pseudomonas phaseoli* E. F. Sm., and some common saprophytes such as *Bacillus subtilis* (Ehr.) Cohn and *B. prodigiosus* (Ehr.) Fleug., were also employed. Figures 25 to 30, with explanations in the list of plates, show in detail characteristic results. These experiments, which were duplicated several times, showed that in general a colony of bacteria which exerted a retarding influence on one species of Fusarium, exerted a similar influence on the other three species. Here again no specificity of "toxic substance" for any certain species of fungus was noted. Some bacteria exerted no observed influence, some accelerated, and some retarded growth of the fungus. The production of mycelium was sometimes changed in quantity, or the color reaction upon the medium was altered. On the whole the Fusaria were very tolerant to the presence of bacteria. No marked alteration of the mycelium or spores was found as a result of the action of the bacterial colonies on the fungus. While the writer has no reason to doubt the authenticity or vigor of the bacterial cultures used, he has not checked this point. Table VII summarizes the observations.

TABLE VII
EFFECT OF BACTERIA ON CERTAIN FUSARIA

	Bacillus atrosepticus	Ps. phaseoli	From rotted potato stem	From rotted seed piece	B. subtilis
F. oxysporum	Slight alteration of growth; aerial mycelium marked	Retarded growth	Retarded growth	Retarded growth medium colored	No change
F. discolor sulphureum	No effect noted	Retarded growth	Retarded growth	Marked retardation	No change
F. from bean	Growth somewhat accelerated, or no change*	Retarded growth	Retarded growth	Retardation	Acceleration* or no change
F. from pea	No effect noted	Retarded growth	Retarded growth	....	No change

* Acceleration of growth did not ensue in every trial. In general, however, the same results were secured in the different tests.

GENERAL DISCUSSION

In considering Fusaria and the diseases they induce, we may first consider these fungi as vigorously growing saprophytes. Their longevity in the soil is a matter of prime importance.

Bolley, in 1901 (5), showed that soil became "flax sick" because of an accumulation of *F. lini;* he stated that when once serious in the soil, "It can live from year to year upon the humus of the soil.... The fungus is able to live in the soil for many years without the presence of a flax crop to feed upon." Orton (40), referring to *F. oxysporum* in the San Joaquin Valley, California, stated that the fungus "may be present in nature in some of these alluvial soils" and at any rate soon accumulated sufficiently in the soil to render potato growing unprofitable. Jensen (26) reported the isolation of *F. oxysporum* from soil from the eastern part of the United States.

It is significant that Pratt (49,50,51,52) found *F. trichothecioides, F. radicicola,* and apparently also *F. oxysporum,* in virgin western soils. Werkenthin (74) found in Texas "that the virgin soil contained fungi which are known to be parasitic to cultivated plants, e.g., *Fusarium Solani* (Mart). Sacc., *Fusarium oxysporum* Schlecht., and *Fusarium radicicola* Wollenweber." These fungi he considered "true inhabitants of the soil." Taylor (68) found Fusarium spp. to a depth of 24 inches, in Rhode Island. Coons (13) obtained what was apparently *F. oxysporum* from native Michigan soils.

There is evidence, then, that *F. oxysporum* may be present in many soils, and may become of considerable importance as succeeding crops of potatoes are grown; it must increase greatly from its growth in roots and stems of parasitized plants, and especially from its development on the dying potato stems and their débris. Such saprophytic fungi are able to withstand various unfavorable environmental conditions and persist in the soil through the production of microconidia and macroconidia, chlamydospores, or "perennating mycelium." In their growth, some Fusaria at least are able to compete successfully with various bacteria and other organisms with which they come in contact.

While Fusaria are active saprophytes, there can be, on the other hand, no question as to their seriousness as plant parasites; their abundant saprophytic growth only renders their control in some respects more difficult. Despite their semi-parasitic nature, many Fusaria, such as *F. oxysporum,* exhibit what amounts to a considerable specificity of parasitism to certain crops. *F. oxysporum,* however, can attack any part of the potato plant; stem, stolon, root, tuber, or even leaf. If the fungus is present in abundance, it can cause a complete rotting off of the stems. It is not surprising, then, that from plants showing atypical symptoms of wilt in the field, *F. oxysporum* should be isolated, especially when the soil and weather conditions are propitious. The Early Ohio variety has been found to be commonly affected, particularly in the Red River Valley. This may be correlated with the fact that the Early Ohio remains through a considerable period in late summer in a condition of slow maturity and lessened vigor.

In regard to the cause of wilting in potato plants into which F. oxysporum has gained entrance, a common explanation is that of mechanical vascular clogging. Link (35) considers the killing of the root system to be as important as this clogging, and Coons (13, p. 302) would add also the systemic poisoning from the production of substances by the fungus. The writer's experiments indicate that the fungus does produce toxic substances, but that various other fungi produce substances equally toxic, the only specificity being in the fact that the other fungi tried are ordinarily unable to gain entrance into the tissues of the plant. It would seem, however, that the three factors mentioned may operate together, with the addition in cases of foot rot of a considerable rotting of the underground portions of the potato plant.

The association of injury to the potato stem from Rhizoctonia or *Colletotrichum atromentarium* (Berk. & Br.) Taub. (67) and of *F. oxysporum* within such stems, and the occasional coincident occurrence of bacteria, Verticillium, or other fungi with *F. oxysporum* indicate that Fusarium wilt ensues more readily when the plant is weakened, and that other organisms may follow or aid the Fusarium in causing injury to the potato plant.

Tisdale (70) has shown that the method of infection by *F. lini* is through root hairs, stomata, or epidermis; in resistant flax the plant was enabled to cork out the perhaps weakened hyphae, which could, however, gain preliminary entrance into the plant. He found further that *F. conglutinans* could penetrate the root hairs of flax, as it normally penetrated cabbage, but in flax it did not develop far. *F. lini* could also probably penetrate the young root hairs of cabbage.

While rots of potato tubers are attainable in the laboratory with various Fusaria, in Minnesota the economically important Fusarium causing rot of tubers is, as far as the writer's evidence goes, *F. discolor sulphureum*. *F. oxysporum* may injure the tuber somewhat by development at the stem end or considerably in the vascular system, or occasionally by causing a rot; other Fusaria more rarely cause dry rot alone or in association with other organisms. *F. discolor sulphureum* evidently lives over especially in storage houses; the writer has observed it in the fall growing luxuriantly, particularly on dirt floors and walls and on débris in potato houses that had held potatoes the previous year.

Infection of the tuber may sometimes apparently ensue from contamination with the organism from the field. Once this fungus gains entrance it can develop at ordinary temperatures regardless of the humidity in storage, tho lower humidity obviously lessens the liability of infection. Relatively low temperatures, particularly cold storage, (1 to 3 degrees C.) allow but slight progress of the disease.

While *F. discolor sulphureum* ordinarily gains entrance through wounds, it is worthy of note as reported above that it may sometimes evidently infect through lenticels. In this connection it may be noted that Pratt (49) found that *F. radicicola* might infect the tuber through the stem end, lenticel, or eye; Wilcox, Link, and Pool (75) and Pratt (51) found that *F. trichothecioides,* on the other hand, infected only through bruises or other injury. Experiments and observations indicate that tubers become naturally infected with *F. discolor sulphureum* principally through wounds.

Tomato, cucumber, and some other fruits and various vegetables, especially when mature, may be rotted by several Fusaria. Numerous other fungi, such as *Penicillium* spp., may also rot these plant parts; the action is hardly more than saprophytic growth upon easily available food material. While various fungi such as Penicillium spp., Aspergillus spp., *Stysanus stemonitis,* Verticillium sp., Alternaria sp., are often found on or in rotted tubers or on healthy tubers, inoculation experiments failed to show any noteworthy ability of these fungi to rot the potato. The normal tuber is not an available source of food for them. Certain Fusaria are also unable to utilize readily the potato tuber as a food supply.

CONTROL MEASURES

POTATO WILT

The methods of control ordinarily recommended are clipping the stem ends and rotation of crops. The former method, while of undoubted value in removing some infection as well as the somewhat weaker eyes near the stem end, is not effective in seriously infected soils. Whether or not *F. oxysporum* occurs naturally in Minnesota soils, it is now widely distributed in the potato growing regions. Observational evidence has failed to show that this fungus seriously attacks other crops in the state. It undoubtedly remains in some abundance in Minnesota soils for a considerable time.

It seems to the writer that the observation that the Fusarium causing potato wilt in Minnesota attacks the plants more especially at the time when blossoming, tuber setting, and hot weather have reduced the vigor of these plants, offers considerable hope in the development of control measures. From this standpoint the utilization of more vigorous strains of potatoes, rotation of crops, improvement of the seedbed, clean culture, and other factors tending to produce more vigorous plants likewise lessen the liability to attack by *F. oxysporum*.

The writer is uncertain as to the interpretation to place upon the data presented by Manns (36, p. 317-319) and considered as tending to show that the "fungus will average in sick fields as great a percentage in reduction under favorable conditions as under drouth." Manns evidently bases this conclusion on the fact that a three-year rotation plot at the Ohio station yielded in 1909 only 69 bushels per acre, whereas the county averaged 186 bushels per acre. It would seem, however, that throughout that county, in which the wilt had presumably been present previously (l.c., p. 311), it could not have greatly reduced the yield in 1909 despite the supposed higher percentage of seed infection in 1908 (l.c., p. 319; see also yield of spray plot, as noted below). Of course this does not explain the low yield in the rotation plot at the Ohio station in 1909.

The work of Manns with bordeaux mixture is also significant. He found that despite the fact that "the only active factor at work in 1909 in reducing the yield on the area plotted for spraying was the work of the Fusarium blight, which was very prevalent . . . the growth in all sprayed plots continued from one to three weeks longer than in the unsprayed," with an average yield of 170.36 bushels per acre in the unsprayed and 181.72 bushels per acre in the sprayed plots. He adds, "The writer is satisfied that spraying heavily four times during the season does somewhat retard the action of the Fusarium fungus. Just how the results are brought about can not be satisfactorily explained." It would seem that the explanation may lie in the increased vitality of plants which are sprayed, and which can thus resist the action of the semi-parasitic *F. oxysporum*. Stewart (66) had previously in New York State obtained a yield of 266 bushels per acre from tubers obtained from wilted vines and in which "when cut at the stem end, blackened fibers are seen penetrating the flesh to a considerable distance." This plot was sprayed thoroly eight or nine times with bordeaux mixture. While it is not certain that Stewart was dealing with *F. oxysporum* wilt, the results obtained are comparable to those secured by Manns.

The writer has obtained as yet only empirical and fragmentary evidence as to the effect of spraying upon the occurrence of wilt in Minnesota. In the northeastern states, where spraying is commonly practiced, wilt is not prevalent. It must not be forgotten, however, that in this region cool weather and other conditions are more favorable to the production of healthy and vigorous plants than in warmer regions.

The results secured in Minnesota' by A. G. Tolaas and certain county agents in the use of seed-plot methods, including selection, treatment, rotation, and good cultural conditions, indicate that wilt may be lessened by methods which tend to add vigor to the plants. A. G. Newhall, in 1918, found a case in point: A field in Cass County, a portion of which had received some care, had 15 per cent of wilt, whereas in another portion in which negligence had allowed weeds to develop and the potato plants to become less thrifty, 30 per cent of wilt occurred.

Removal of débris from a field that had grown potatoes would lessen considerably the amount of culture medium for the Fusarium. The consideration involved as to fungi in returning such débris to the field after a period of rotting, is undetermined.

POTATO DRY ROT

Control measures that may be used against the rot caused by *F. discolor sulphureum* have not been found to be different from those recommended by various writers against other fusarial dry rots. Highly important is more careful handling of potatoes during and after digging to avoid cuts, bruises, and injuries, since the fungus attacks the tubers ordinarily and most easily through wounds. Storage cold enough to prevent absolutely the development of this rot is hardly attainable in any storage facilities possessed by the average grower, except possibly in the use of pits in the field. Considerably less infection would probably result, however, if the storage rooms were thoroly disinfected before potatoes were put in, and cleaned out carefully after the potatoes were removed. A disinfection of the tubers before storage would probably be commercially profitable, at least in the case of seed potatoes.

Control measures against root rots of truck crops are indicated in the rotation of crops and the most favorable growing conditions for the crop. Careful handling and clean cool storage of fruits and vegetables subject to Fusarium rots will reduce the injury.

SUMMARY

1. *Fusarium oxysporum* Schl. is the cause of one of the most serious diseases of the potato plant in Minnesota.

2. This fungus characteristically produces the symptoms known as wilt. It attacks the roots and lower stem of the potato plant, particularly during the blossoming and tuber setting periods, when the weather is likely to be unfavorable to the potato, tho not to the fungus. *F. oxysporum* can moreover attack any part of the potato plant, and under certain conditions, particularly in wet soil, causes darkening and rotting of the stem and other symptoms not typical of wilt. It may rot the seed tuber under field conditions.

3. As a saprophyte, *F. oxysporum* grows vigorously on the affected potato plants, accumulates in considerable abundance in the soil throughout the season, and persists for some time. In the fall it may attack plants which have previously produced a normal crop of tubers.

4. The strains of *F. oxysporum* used were not, under ordinary conditions, sufficiently active parasites to cause infection of younger potato plants from artificial inoculations of the soil or seed tuber. At higher temperatures, symptoms of disease may occur. If the soil is inoculated heavily, rotting of the seed tuber and of the sprout or stem may result.

5. Wilted plants do not necessarily result from planting seed tubers from affected plants. While such "seed" is less satisfactory than tubers produced under healthy vines, other measures in addition to seed selection or clipping off the stem ends are necessary to avoid wilt.

6. While *F. oxysporum* is largely confined to the potato in Minnesota, its habits are for the most part hemi-parasitic.

7. The danger of serious infection by the wilt Fusarium is lessened by measures tending to add to the vigor of the plants, particularly during the latter part of the season.

8. *Fusarium discolor sulphureum* is the common cause of storage dry rot of potato tubers in Minnesota.

9. This fungus gains entrance commonly through wounds, tho the rot may sometimes be induced by applying the fungus to the uninjured surface of the tuber.

10. Tubers from normal potato vines rot as readily as those from "constitutionally degenerate" plants, and as readily as tubers showing frost necrosis. None of the varieties of potatoes tested was found to be resistant to this tuber dry rot.

11. Rot may develop on unsprouted tubers, and under dry conditions. Very slight rot may develop even at temperatures below 2 degrees C.

12. At temperatures below about 16 degrees C., *F. discolor sulphureum* produces more abundant aerial mycelium; at temperatures of from 20 to 30 degrees C., a dense pseudopionnotes.

13. The starch grains in the tubers affected with dry rot are not appreciably affected.

14. *F. discolor sulphureum* does not naturally cause a wilt of potato plants, but infected seed tubers may produce less vigorous sprouts, or even no sprouts.

15. While other Fusaria, such as *F. oxysporum* and *F. culmorum* may cause rot of potato tubers, such rots have been found to be of little economic importance in storage.

16. Careful handling of tubers and the maintenance of clean cold storage conditions, are important prophylactic measures against the storage rot caused by *F. discolor sulphureum*.

17. Fusarium root rots of *Pisum sativum* and of *Phaseolus vulgaris* are of importance in Minnesota.

18. Ear rots of *Zea mays* due to Fusaria, probably including *F. culmorum*, are common in the state.

19. Cross-inoculations indicate that wilt or root rot producing Fusaria may exhibit a selective tendency in their more common occurrence on certain species of host plants, altho hemi-parasitic in that their action may be more distinctly influenced by conditions unfavorable to the host.

20. A temperature at which the host develops poorly may allow an active development of the attacking Fusarium.

21. Isolations and cross-inoculations demonstrate that no single species of Fusarium is chiefly responsible for the common storage rots of vegetables and of cucumber and tomato fruits.

22. Fusaria produced substances in old solutions that inhibited the germination of spores of the same or other fungi. After boiling, such old solutions allowed normal germination.

23. Substances detrimental to such plants as potato, coleus, and ragweed, as shown by the wilting of excised leaves when placed in solutions, were also produced by Fusaria and other fungi in cultures. This injurious effect persisted after boiling, neutralization, or some dilution of the solutions. Specific fungi did not produce substances selectively injurious to any one or more plants.

24. Fusaria are, in general, little influenced by bacteria, tho some bacteria may influence the rate of growth of Fusaria.

25. The Fusaria examined could withstand considerable dessication, exposure to low temperatures or to alternate freezing and thawing, and can utilize a wide variety of food substances. Altho important parasites, Fusaria are efficient saprophytes.

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EXPLANATION OF PLATES

Figure 1. Plant showing typical wilting. Illustration by the courtesy of H. A. Edson of the United States Department of Agriculture. Taken in a field in Clay County, Minnesota, August 11, 1917.

Figure 2. Rather early stage of wilting. Taken by Dr. Edson, also in Clay County, August 11, 1917.

Figure 3. Plants collected August 23, 1918, from Clay County, illustrating the browning and rotting of the lower stems and of the roots. One plant also injured by stalk borer. Isolations yielded *Fusarium oxysporum* from these and similar plants.

Figure 4. Plants showing similar and serious injury from foot rot, collected August 22 and 23, 1918, from Polk and Clay counties. The large plant illustrates also the external production of fungus after having been in a damp place about two days.

Figure 5. Tubers from plants showing foot rot, collected in Polk County, August 22, 1918. *F. oxysporum* and secondary fungi and bacteria present, causing a rather soft rot of the tubers. This rot was not ordinarily foul smelling. The blackening shows some tendency to follow the fibro-vascular bundles.

Figure 6. Seed piece inoculated with *F. oxysporum,* received February 8, 1915, from W. A. Orton. (No. 3394 from Wollenweber's laboratory.) Inoculation September, 1917. The seed piece had rotted, the fungus was present in the stem. Reisolations yielded *F. oxysporum.*

Figure 7. Cage heated by carbon electric lamps to secure higher temperature.

Figure 8. Results of rather heavy inoculation of sterilized soil with *F. oxysporum* in the warmed cage. Seed piece rotted, one stem rotted off, other injured at the base. March, 1918.

Figure 9. A case similar to Figure 8. Stems rotted off or seriously injured at the base. March, 1918.

Figure 10. On the left, plant growing in the warm chamber in sterilized soil infected with *F. oxysporum.* Moist conditions did not allow a serious wilting, but the plant is affected, particularly as indicated by the upper leaves. On the right, check grown from the same seed in sterilized soil. February, 1918.

Figure 11. Affected plant growing in artificially infected soil. The lower leaves have fallen and the plant is unthrifty. February, 1918.

Figure 12. Surface view of tubers affected with *F. discolor sulphureum* from Beardsley. The wounds from which infection occurred can be seen on the surface. January, 1918.

Figure 13. Longitudinal sections of the tubers shown in Figure 12. The rotted tissue is dark brown or blackish, containing some "pockets" filled with mycelium and sporodochia of the fungus.

Figure 14. Stem and eye end infection of tubers from Clay County and characteristic of the rather early stage of a considerable infection in that region. Received December 10, 1917.

Figure 15. Effect of injury, moisture, and temperature on the development of rot by *F. discolor sulphureum.* Figures A to E, inclusive, no injury to the surface; inoculum applied to the uninjured epidermis. Figures F, G, and H, slight injury to the surface before inoculation. Figures I to L, considerable wounding of surface previous to inoculation. Figures A and B, room temperature, damp. Figures C and D, room temperature, in a dessicator. Figure E, icebox (8 to 10 degrees C.), damp. Figure F, room temperature, damp. Figure G, room temperature, dessicator. Figure H, icebox, damp. Figure I, room temperature, damp. Figure J, room temperature, dessicator. Figure K, room temperature and room humidity. Figure L, icebox, damp.

Figure 16. Weak plant secured from planting seed partially rotted with *F. discolor sulphureum.* March, 1918.

Figure 17. Healthy plant from seed tuber planted at same time as that of plant shown in Figure 16. Some rot on seed when planted. The rot did not, however, progress much. March, 1918.

Figure 18. At left, base of plant shown in Figure 16, seed rotted; center, base of plant shown in Figure 17, seed healthy at insertion of stem. At right, another plant similar to the one on the left. March, 1918.

Figure 19. Pea seeds rotted and roots and lower stems of young plants affected with Fusarium isolated from pea plants. Greenhouse inoculations, September, 1917.

Figure 20. Four tubers at left show slight rot, with *F. discolor sulphureum* developed at 1.1 to 1.7 degrees C. Plugs cut out of potatoes in inoculating. The browned vascular ring in some of these tubers is due to frost necrosis, which had developed prior to the subjection to cold storage. Previous experiments demonstrated that this slight necrosis had no influence on the rate of rotting. At the right, a tuber almost wholly rotted when placed in cold storage. The rot progressed little at the temperature mentioned. This tuber was cut before being put in cold storage and shows the development of some mycelium on the cut surface. Duration of experiment, 31 days, March 16 to April 16, 1918.

Figure 21. Rot of potatoes from *F. discolor sulphureum* at 8 to 10 degrees C., artificial inoculation, two weeks' development.

Figure 22. *F. discolor sulphureum*: center of plate, mycelium produced at 8 to 10 degrees C.; area of less abundant mycelium produced at room temperature, containing many small sporodochia not shown clearly; circumference, mycelium produced again at 8 to 10 degrees C.

Figure 23. At the right, tuber rot secured at 25 degrees C. with *F. culmorum* from wheat; at left, rot by same fungus at room temperature (about 18 to 20 degrees C.). Time, two weeks.

Figure 24. Rot started by *F. lini* on potato tuber. Time, two weeks.

Figure 25. *F. oxysporum* inoculated January 25, 1918, in the center. The stained area (dark red in natural color) shows the area occupied by a colony of bacteria obtained originally from a rotted seed piece and as yet unidentified, over which the fungus grew slowly, as indicated by the lines marking dates. Opposite this a colony of *Bacillus atrosepticus* was present, but exerted no influence on growth or production of color. A colony of Aspergillus at the margin opposite the stained area checked the growth of the Fusarium. View from lower face of Petri dish.

Figure 26. View from above, showing mycelium of *F. oxysporum* growing over a colony of *B. subtilis*: aerial mycelium marks the margin; no pause in the growth. The radii, etc., on the opposite side are due possibly to shrinkage of the medium.

Figure 27. *F. discolor sulphureum* retarded by a colony of bacteria (the same species of bacteria mentioned for Figure 25, obtained from a rotted seed tuber). The fungus eventually grew completely over this colony; the conidia and mycelium produced thereon appeared normal microscopically. Opposite, a colony of *Bacillus atrosepticus* had exerted no influence upon the growth. This figure illustrates the ample macroconidial production at room temperature. View from above.

Figure 28. Fusarium from bean plant. The irregular bacterial colony, checking growth somewhat, is *Pseudomonas phaseoli*. (The fungus finally grew entirely over this colony, but more slowly.) Opposite roundish colony is *B. subtilis*. The growth of the colony was noticeably accelerated when this colony was reached, just as the growth has been accelerated on the lower side, where the fungus has pushed out over a colony of *B. atrosepticus*. "Growth arresting and accelerating" substances are evidently produced. The organisms shown in Figures 25 to 28 grew on potato dextrose agar under a bell jar at room temperature. Inoculations January 25, 1918, photographs February 5, 1918.

Figure 29. At right, relation between bacteria from a soft-rotted potato and (1) *F. oxysporum*, (2) *F. discolor sulphureum*, (3) Fusarium from pea, (4) Fusarium from bean. Bacteria inoculated in center November 9, 1918, fungi inoculations November 12, photograph November 15. The growth of the fungi was somewhat retarded, and the bacteria tended to grow between the fungous colonies. At left, *B. atrosepticus* in center. Fusaria numbered as at right, inoculations and photographs same date.

Figure 30. At right, *B. subtilis* in center, exerting little influence on the Fusaria. At left, a colony of bacteria isolated from a potato stem has diffused substances through the medium checking equally the growth of the four Fusaria. Reciprocally, the bacterial colony ceased to enlarge. Inoculations in both plates: bacteria, November 9, 1918. Fusaria, November 14, photograph November 25.

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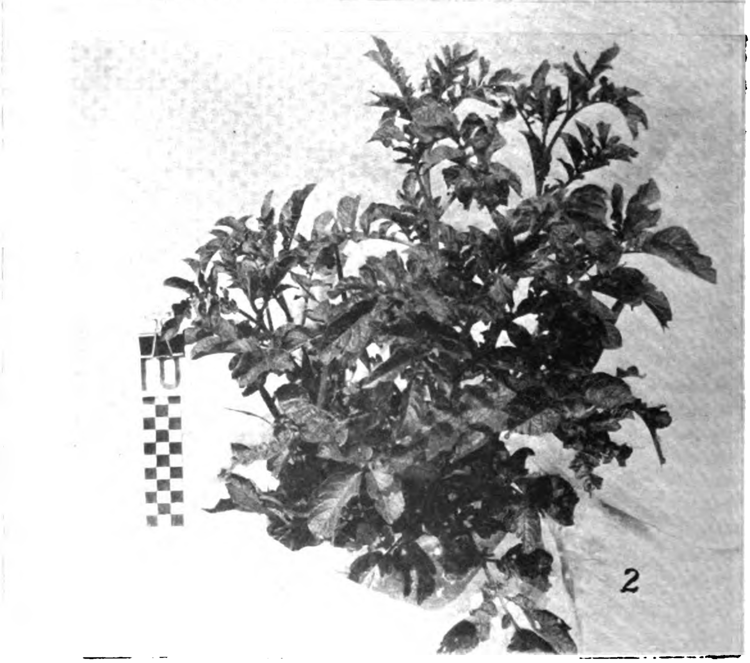

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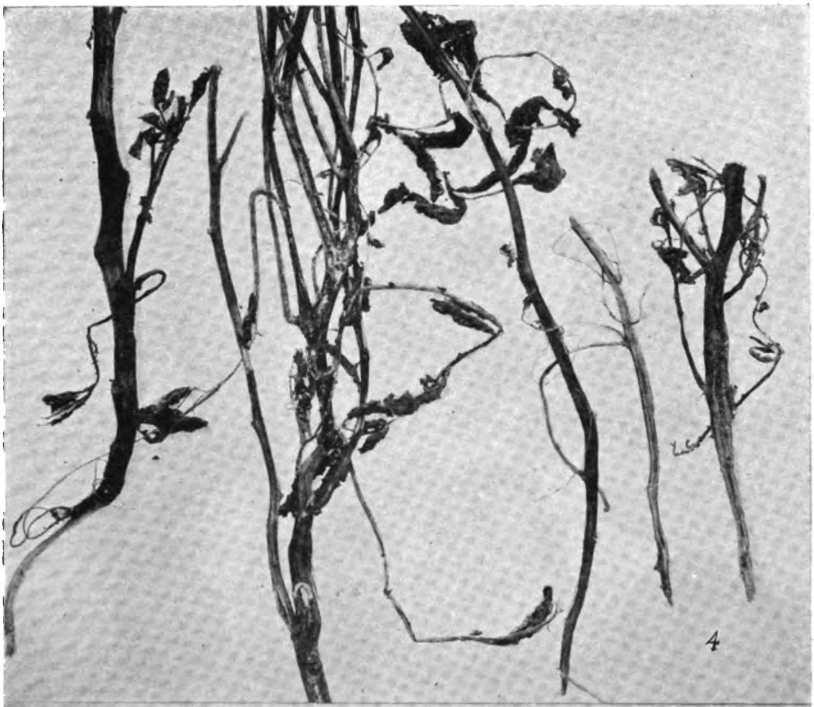

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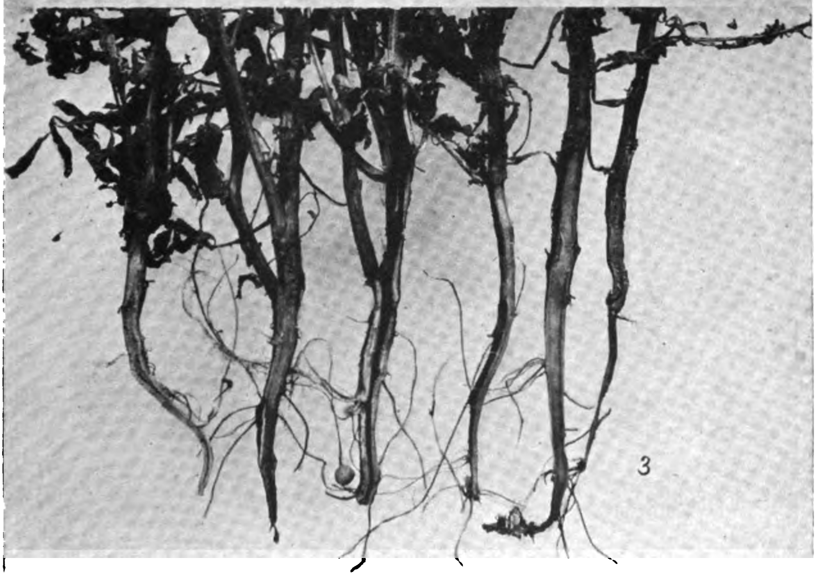

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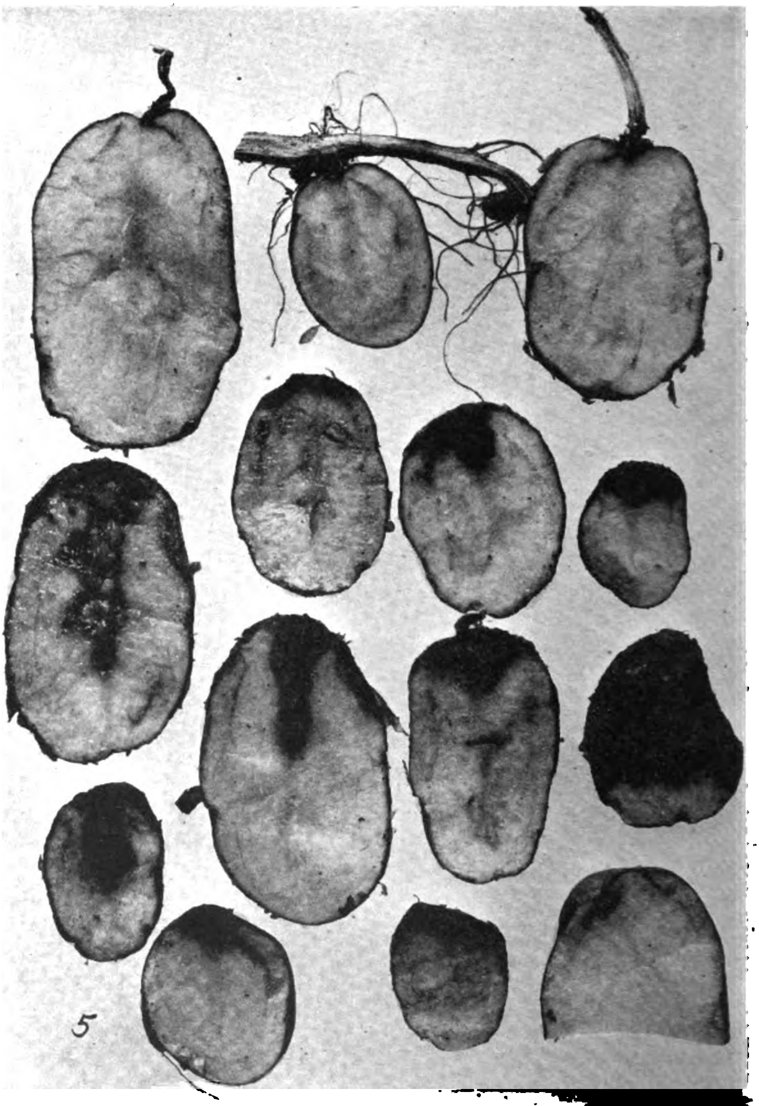
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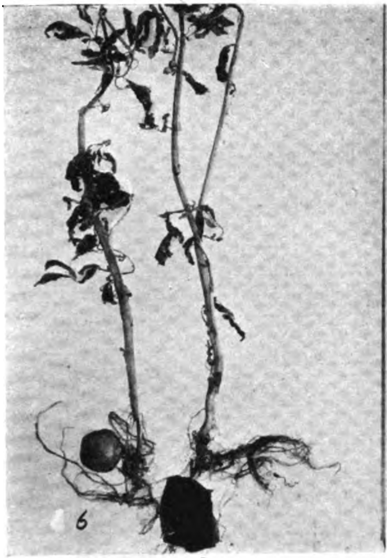

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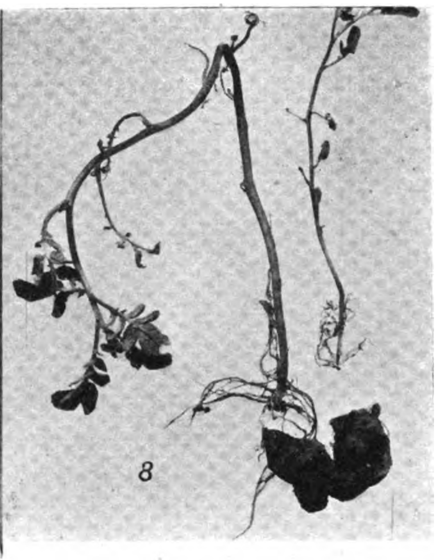

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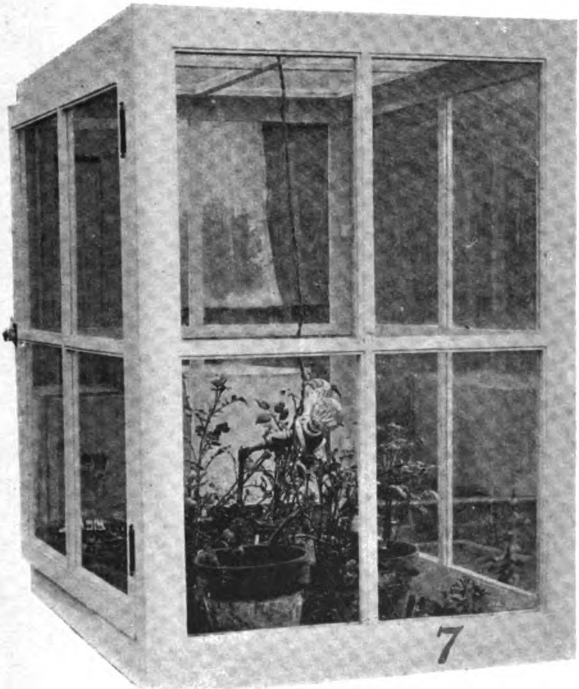

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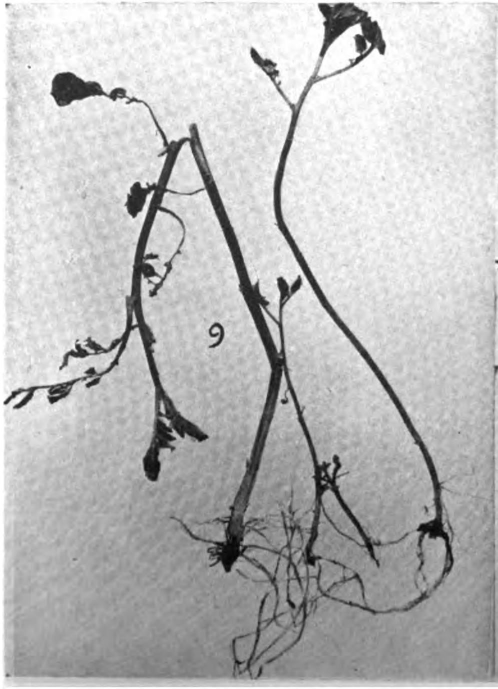

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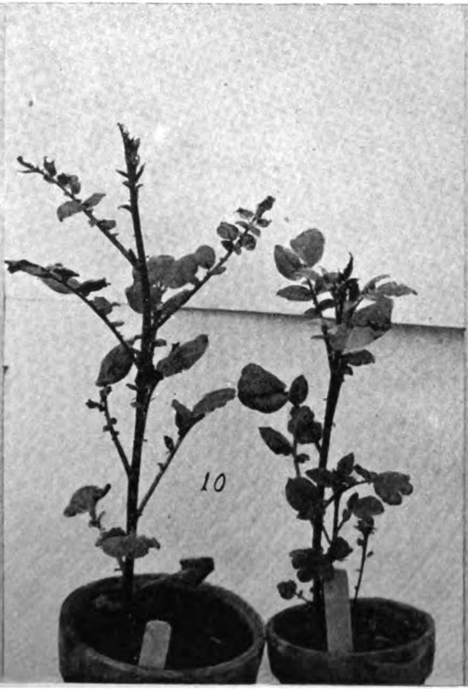

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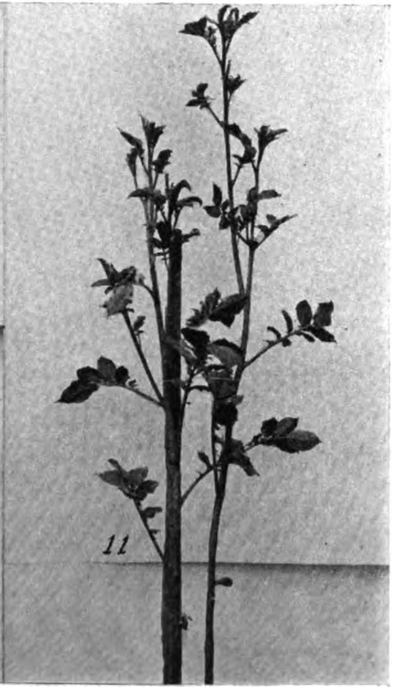

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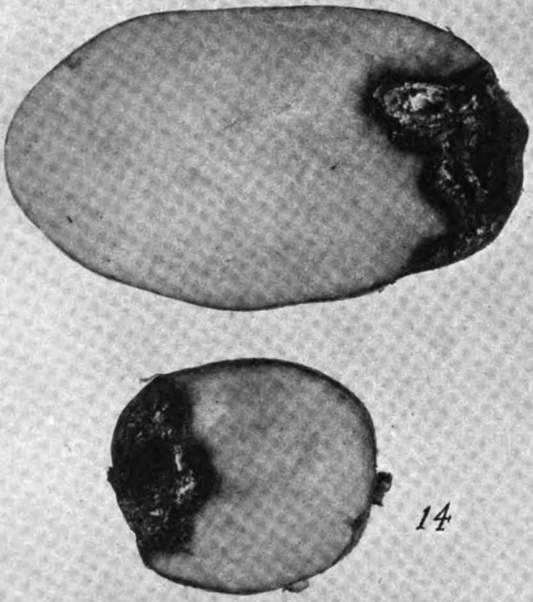

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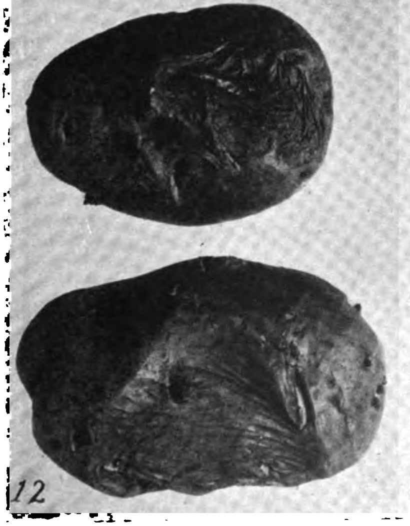

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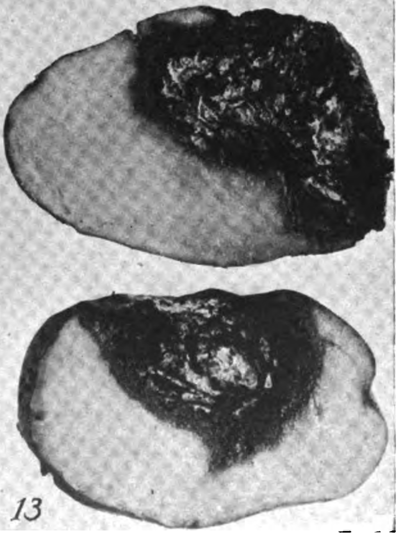

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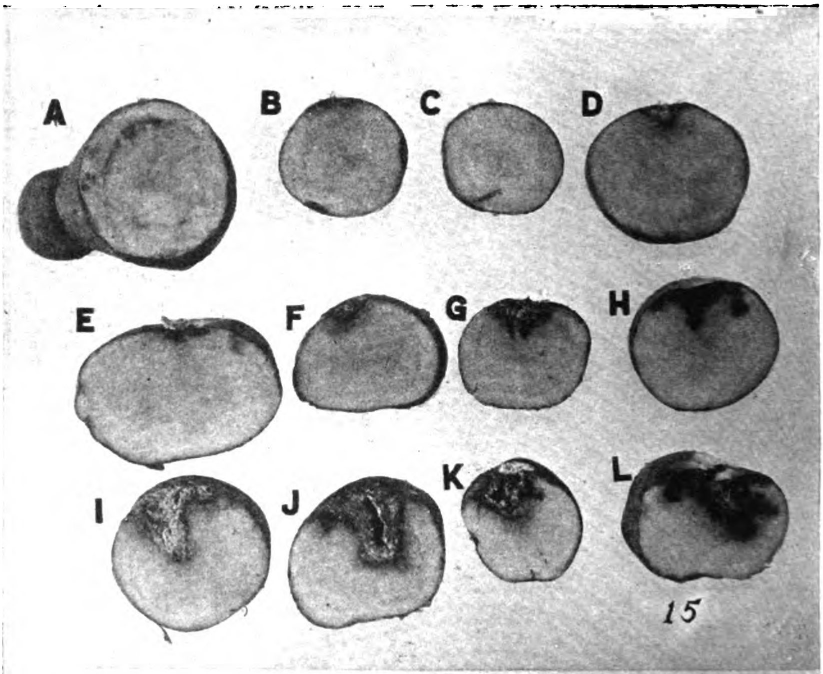

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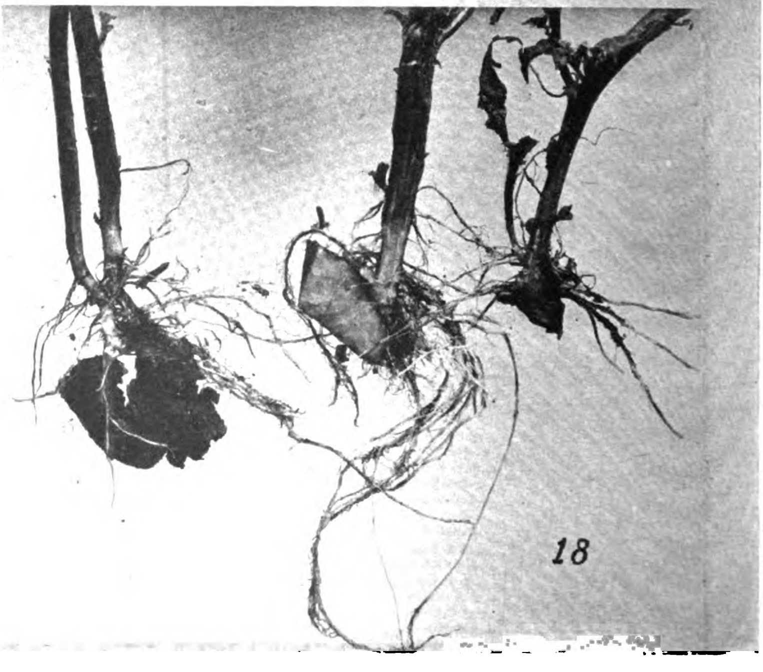

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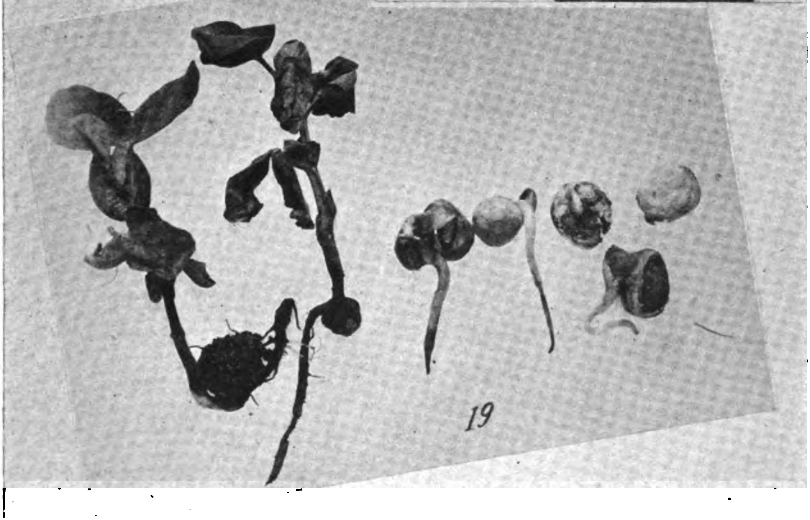

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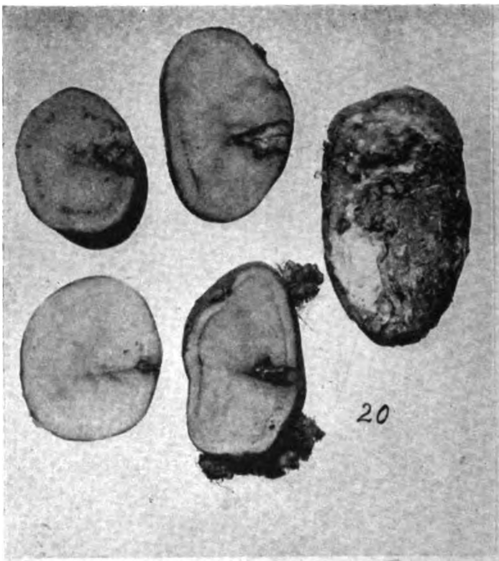

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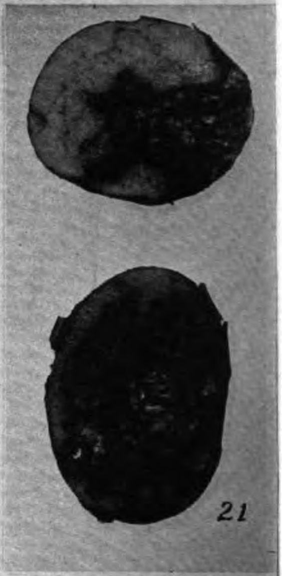

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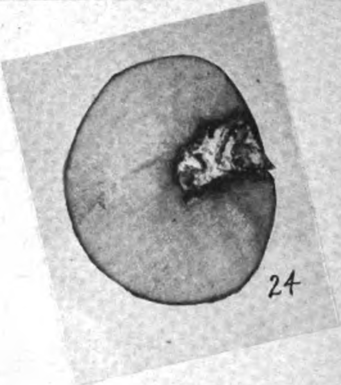

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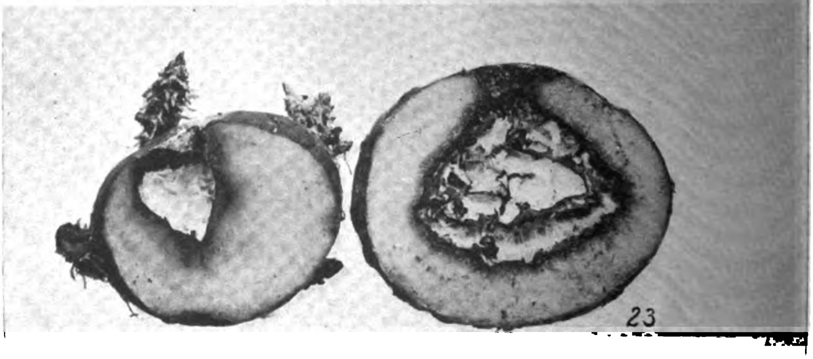

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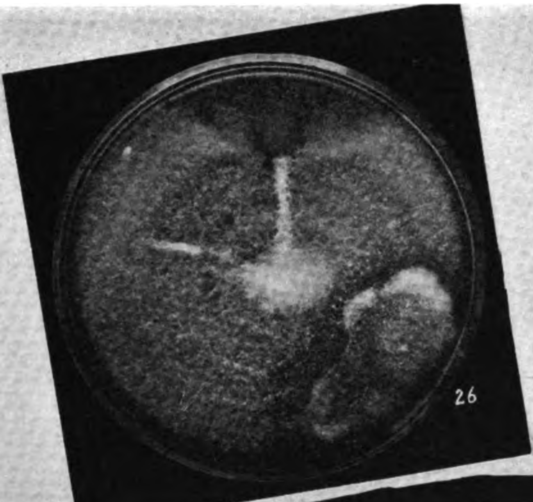

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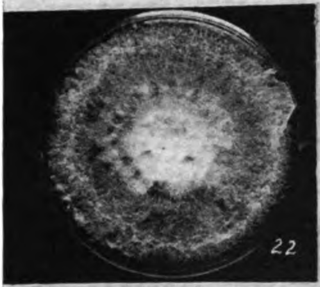

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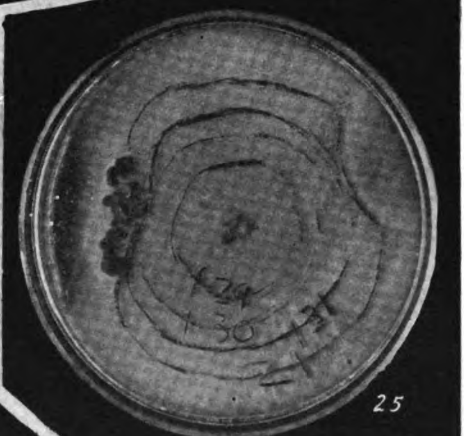

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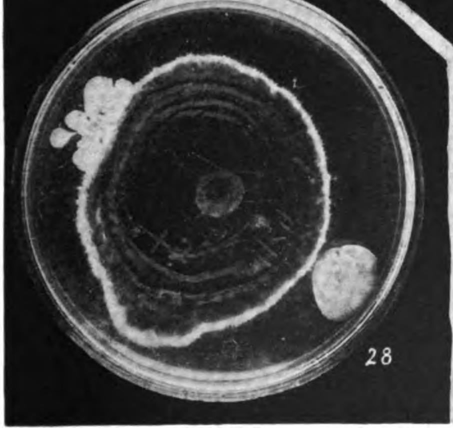

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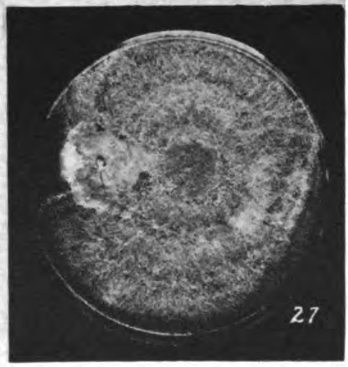

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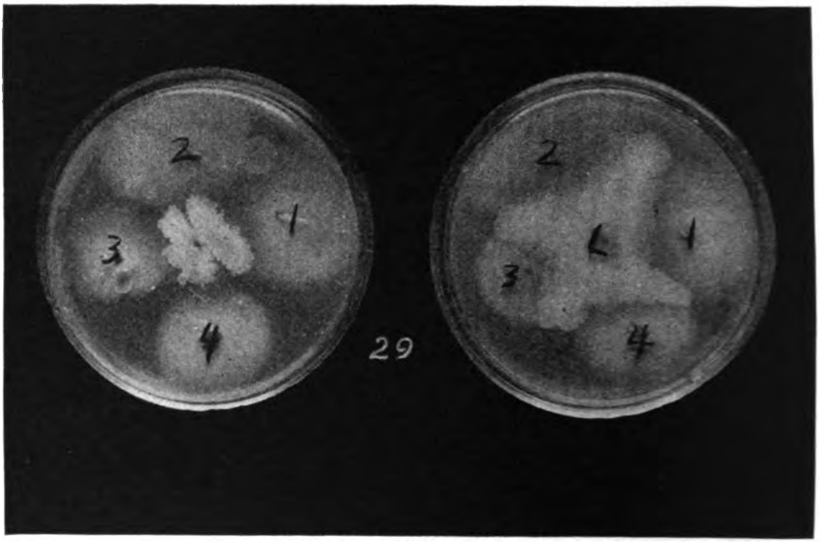

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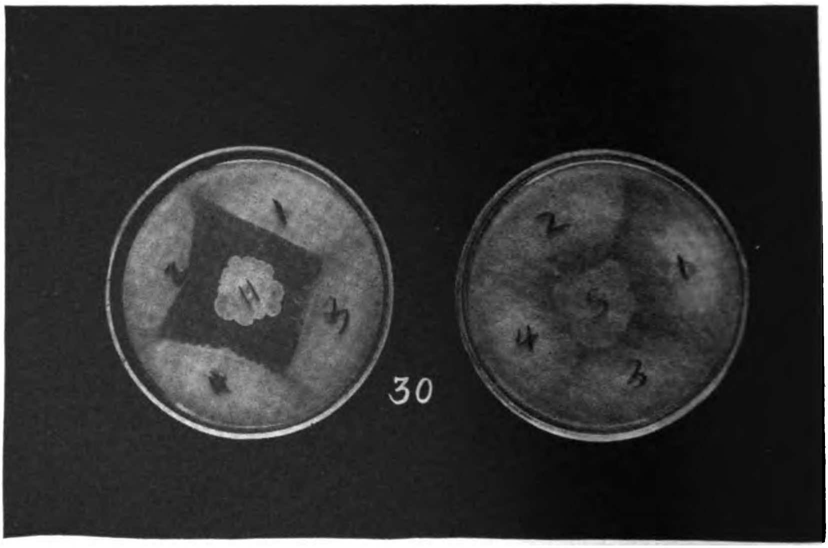

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BULLETIN 182 MARCH 1919

The University of Minnesota

AGRICULTURAL EXPERIMENT STATION

BREEDING SMALL GRAINS IN MINNESOTA

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BY

H. K. HAYES AND R. J. GARBER

PART II. BARLEY INVESTIGATIONS

BY

H. V. HARLAN AND H. K. HAYES

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BREEDING SMALL GRAINS IN MINNESOTA

PART I. TECHNIC AND RESULTS WITH WHEAT AND OATS.

By H. K. HAYES and R. J. GARBER

INTRODUCTION

There are two main forces which control crop production. These are environment and heredity. The work of the plant breeder is to find or produce those strains or varieties of our various crops which will give the greatest possible return in bushels of grain or pounds of forage under certain given environmental conditions. The purposes of this bulletin are to give: (1) Technic of breeding small grains as carried on at the Minnesota station and results with wheat and oats, special attention being paid to certain improved forms. (2) To report results of coöperative barley breeding investigations.

METHODS OF TECHNIC

Breeding of small grains was first started at this station by W. M. Hays about 1891. The method used was probably based on the plant as the unit altho continuous selection was also practiced. These early investigations (Hays and Boss 1899) gave results of much economic importance to Minnesota farmers.

As a result of more recent studies of inheritance due to the rediscovery of Mendel's law, plant breeding methods are becoming somewhat standardized. Studies in field technic from the standpoint of size, shape, and replication of plots have also greatly assisted in obtaining accuracy.

The work in plant breeding as now carried on here is based on certain principles which may or may not be true from the standpoint of the student of evolution, but which are commonly accepted by plant breeders who are familiar with studies in genetics. The more important of these are as follows:

1. Continuous selection in the progeny of a pure line of self-fertilized crops is of no value from the standpoint of the plant breeder.
2. Mutations in such pure lines may occasionally occur but they are too infrequent to be of much value as a basis for further selection.
3. Segregation in crosses for all characters by which the parent plants differ is the rule.
4. Varieties of hybrid origin which have been purified are as stable as varieties which are the result of selection in commercial sorts.

Improvement of self-fertilized crops falls naturally under the following heads: (1) New introductions, (2) Selection, (3) Crossing.

METHOD OF KEEPING CONTINUOUS RECORD

When a new introduction is first brought to Minnesota it is listed in the accession number book, one such book being kept for each crop. The history, source, and other data are also entered. If grown in field variety plots by the farm crops section it is carried only under the Minnesota accession number. If it enters the breeding nursery it is placed in Class III with the year of its introduction. Thus, a wheat introduced in 1918 would appear as Class III-18, together with the Minnesota accession number.

All individual plant selections from new introductions or commercial varieties are placed in Class I. The year in which the selection is first grown is also carried, together with a nursery series numbered from 1 to as many heads or plants as are selected in any particular season. Thus, if 500 heads of wheat are selected in Minnesota accession No. 471 in 1918, these would appear as I-19-1 to I-19-500, the Minnesota accession No. 471 also being used.

Crosses are placed in Class II. For the first few years the method of numbering used by the United States Department of Agriculture is followed. Thus, a cross made between I-14-1 and I-14-6 is labeled I-14-1 × I-14-6. On growing this a convenient number or letter is used. Later generations, in the latter method, would appear as A for F_1, A-1 for F_2, A-1-1 to A-1-200 for 200 head selections grown in F_3. As soon as a cross is purified, that is, appears homozygous, it is placed in the rod row yield test and given a nursery series number.

Thus, we would label our cross made in 1918 as follows: Cross I-14-1 × I-14-6 would be labeled in F_1 as Class II-18, A, in F_2 Class II-18, A-1, in F_3 as Class II-18, A-1-1 to A-1-200. As soon as any particular line appears homozygous it receives a series number—for example, II-18-1 would refer to a homozygous selection from the cross made in 1918.

NEW INTRODUCTIONS

The successful plant breeder recognizes the place of new introductions. There is no use attempting to produce a variety which is adapted to a particular condition if the qualities desired are to be found in some variety already grown in another locality or country.

The United States Department of Agriculture has a trained corps of workers who are constantly introducing new plant sorts from foreign countries. At the present time the Office of Cereal Investigations of the Bureau of Plant Industry acts as a medium for the introduction of new varieties of small grains. Through coöperation there has been a consistent attempt to obtain all promising new introductions of small grains as a basis of further breeding work.

When a new introduction is first brought to Minnesota, it is planted in a short row the first season, all rows being spaced one foot apart. Little attention is paid to the performance this year, altho those sorts which are clearly undesirable are immediately discarded. The following season a single 18-foot row of each new introduction is planted and after removing a foot from each end, the 16-foot row remaining is harvested and yield and other characters taken. Those sorts which are at all promising as determined by the first two years' results are tested the following year in comparison with standard varieties. For all such tests three systematically distributed 18-foot rows are used. Those introductions that give results of promise by this test are then used as a basis of pure-line selection.

SELECTION

The head-selection method is used for the purpose of isolating the best possible pedigreed strain of the variety in question. From fifty to two hundred heads of each promising commercial sort are selected.

A head row of each selection is grown the first year. Those which seem of inferior vigor, have exceptionally weak straw, or have other undesirable characters, are immediately discarded. The following year each selection is grown, if sufficient seed is available, in three systematically distributed plots of a single 18-foot row each, one foot being removed from each end of all rows before harvesting.

In subsequent years three plots of three rows each are used for each selection in the test. Central rows only are harvested for computing yield; the border rows being grown for the purpose of overcoming competition between different varieties (Hayes and Arny, 1917) (Kisselbach, 1918) and to obtain more accurate data on lodging.

A check plot of a standard variety is grown every third to fifth plot and the yield taken. Standard deviations for yield of this standard sort are computed and the probable error for the method of test obtained by multiplying the standard deviation by 0.6745. This probable error is multiplied by 3[1] and when subtracted from the highest yielding sort a somewhat arbitrary figure is obtained, below which it is considered safe to eliminate all strains for the season in question without danger of discarding a high yielder. If a strain is thus eliminated for two successive seasons it is immediately dropped from the test.

After a three-year trial the few very promising sorts are placed in the final variety test, which is carried on by the farm crops section. As a general rule this test is continued for three years before the new sort is introduced, altho in special cases the variety may be introduced more quickly. Thus from seven to nine years elapse before a new selection is distributed to the farmers.

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[1] With a difference of three times the probable error the chances are 21 to 1 that the result is significant from a mathematical standpoint.

Methods of improvement of small grains by selection, as used at the Minnesota station, are here given in summarized form:

1. Determination of the varieties which possess economic possibilities.
2. Head selection of these promising varieties.
3. The head row test. The very undesirable discarded in the field by inspection. A few discarded in the laboratory.
4. Those selected by the foregoing method tested in three plots of a single row each, these rows being systematically replicated.
5. Three systematically distributed plots of three rows each used in the following year's test. Very undesirable types discarded.
6. Standard deviation for the averages of the yields of three check plots multiplied by 0.6745 gives a probable error for the method of test. Three times this error subtracted from a higher yielding sort gives a figure below which sorts may be eliminated for the season in question. If so eliminated for two successive years the strain is immediately discarded.

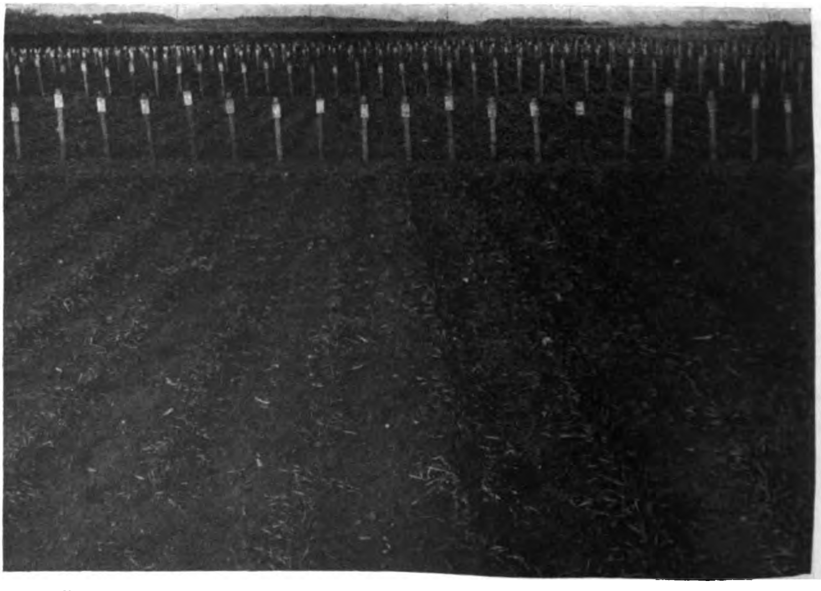

Fig. 1. General View of Rod Rows in Winter Wheat Nursery, Fall of 1915

7. Promising strains tested for two or three years in row tests and then placed in variety test.
8. A few of the most promising also tested at substations in rod rows.
9. Purity plots of 50 plants each grown to insure pure seed of each strain under test, providing much mixture appears in the rod rows.

Thus, four years are needed for the nursery trial after the selection has been made and three years for the final variety test which is made by the farm crops section.

CROSSING

The improvement of our commercial sorts by the individual plant method of selection is a very easy process, altho several years are required to do the work. The production of new forms by crossing is not so simple and there is need of very close study by the breeder. In this work we have attempted to develop a standard method. As carried on, the details are simply the application of the Mendelian or individual plant method of procedure.

The first step is the initial cross. Promiscuous crossing is not practiced, but each cross is the result of a determination of parents which most nearly approach the ideals in mind. By recombination of characters there is then the hope of obtaining a sort which is more desirable. As an illustration of methods along this line certain problems may be cited.

The initial step in the production of a hardy, high yielding, corneous winter wheat is to obtain the hardier types and for this purpose seed of all varieties of any promise have been obtained by coöperation with the Office of Cereal Investigations, United States Department of Agriculture. A few crosses between hardy types have been made, the most promising being a recross between two purified crosses. One of these parental types is wheat of desirable yield and quality, the other is the hardiest strain which we have yet found.

Sometimes crosses are made with the sole hope of improving yield. Thus, the two common spring wheat varieties grown in Minnesota are Marquis and Preston. By crossing these, recombination for the factors for yield may occur and a type be produced which is of higher yielding ability than either parent. Practical results of this sort have been obtained in breeding winter wheat at the Svalöf station (Nilsson-Ehle, 1911, 1912). Some results presented in this paper are of similar nature. Transgressive segregation for size characters has been reported by numerous workers. Altho prediction as to results can not be made for any particular cross, the methods of attack are now approaching a standard practice.

Most of the crosses reported in this bulletin were made many years ago. After the initial plant selection they were further propagated each year by field selection of ten plants in each one-hundred-plant plot. These plants were selected because of vigor and similar botanical characters. Selection of so many plants delayed purification, altho in recent years it was found to be a very easy matter to produce purity by the single-plant method for these crosses. In reality these types produced-homozygous sorts which were immediately isolated by selecting individual plants. This was a close approximation of the method of work which is frequently used at Svalöf. According to Babcock and Clausen (1918) a bulk plot of a cross is sometimes grown for several years and then individual selection is practiced. This procedure is sound scientifically because of the rapid increase in the proportion of homozygous types in succeeding generations following a cross. The formula for the percentage of homozygous types in any generation is $\left(\frac{2^n-1}{2^n}\right)^m$ when n is the number of generations elapsing since the cross was made and m is the number of allelomorphic pairs involved (Jennings 1912) (Lotsy 1917). This would not absolutely hold unless all the progeny were equally productive numerically and no natural crossing occurred.

Often the breeder can not afford to wait long enough to allow the cross to produce automatically a large percentage of homozygous individuals. The following method is then used:

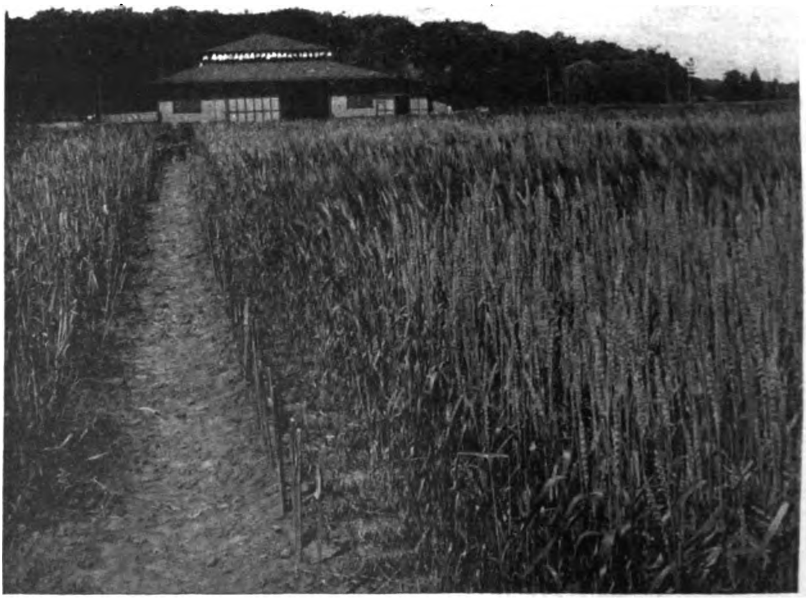

Fig. 2. **Rod Row Nursery Plots**

Eighteen-foot rows are planted and after heading one foot is cut from each end. Three-row plots are used, the central row being harvested for the yield test.

1. The cross is made between parents selected because of their characters.

2. The F_1 generation is grown so that each plant has individual space for development which permits an examination of its characters.

A knowledge of inheritance of special characters often allows those plants which are not crosses to be discarded in F_1.

3. A large plot is grown in F_2 and desirable plants selected. The progeny of each F_1 plant is grown separately in F_2 and thus any plots which do not show segregation for the characters by which the parent plants differ may be discarded.

4. Some of the lines grown from individual F_2 plants breed true in F_3, others segregate for some characters and are homozygous for others, while still other F_3 generations are as variable as the F_2 generation.

5. All lines which breed true in F_3 and which appear promising are placed in the rod row test in F_4 and handled by the method outlined under Selection.

Those which show segregation in F_3, in F_4, or in later generations are again selected by the individual plant method. As soon as any of these selections are homozygous and show promise of being desirable types they are placed in rod rows.

6. A plot of from twenty-five to fifty plants is grown yearly from a single selected plant for each cross which is being tested for yield in the rod-row test. This is done so that homozygous seed is always available for all lines being tested, as experience has shown that it is very difficult to eliminate all accidental mixtures and natural hybrids (Hayes, 1918) from the rod-row plots.

7. If a rod-row plot gives unmistakable evidence of segregation it is re-selected.

WINTER WHEAT

Approximately 70 per cent of the total wheat production of the United States from 1913 to 1917, inclusive, was winter wheat.[2] Minnesota produced slightly more than 6.5 per cent of the total amount, and of this about 98 per cent was spring wheat. The average yield per acre for this 5-year period for the United States was 12.9 bushels for spring wheat and 16.1 bushels for winter wheat. According to the report, Minnesota gave an average yield per acre of 13.7 bushels for spring wheat and 17.4 bushels for winter wheat.

There are three main reasons why winter wheat is preferred to spring wheat:

1. It allows for a better distribution of labor on the farm.
2. It matures earlier, which serves to protect it from rust and drouth.
3. It yields more grain per acre.

[2] Dept. of Agr. Yearbooks.

As winter wheat in Minnesota frequently suffers severely from winter-killing, the acreage is very small. Results obtained at this and other stations show that types hardier than the commercial varieties now grown can be produced by crossing and selection. This bulletin is a report of progress, particular attention being paid to certain hardy forms.

The breeding of winter wheat in Minnesota was started by W. M. Hays in 1898 and has been continued practically as originally outlined from that time until 1915. During this period the breeding nursery has been under the direction of several different men.[3]

Because of the interest of these investigators, many introductions of winter wheat have been tested for hardiness. Varieties have been obtained from all over the world through various agencies. Numerous crosses were made a few years after the winter wheat breeding was started which, together with pedigreed selections, made a good sized nursery each year.

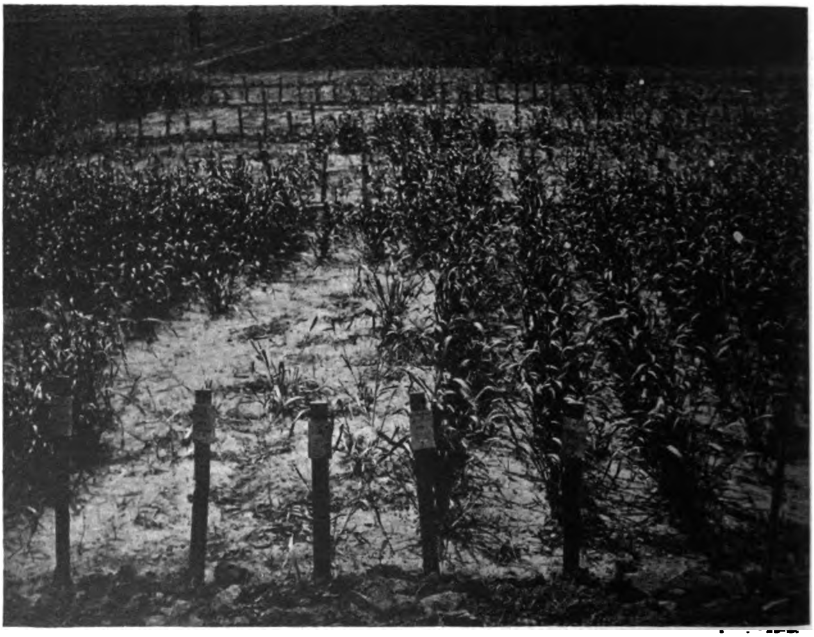

Fig. 3. Comparison of Winter-killing of Turkey × Odessa, Minn. 1505, and Turkey, Minn. 1487

Three rows at right are Minn. 1505; at left, Minn. 1487. Rod-row test, 1918.

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[3] The following have been in charge of the breeding work in small grains: W. M. Hays from 1891 to 1904, Andrew Boss 1905 to 1913, T. B. Hutcheson 1914. Others have directed the breeding of particular crops. The following deserve mention: W. W. Pendergast, C. S. Scofield, C. P. Bull, E. C. Parker, and F. Knorr. Two men have acted as nursery foreman: Alex Carlyle to 1907 and Lee Alexander from 1908 to the present time.

The method of breeding from 1898 to 1914 was that originally outlined by W. M. Hays, which is known as the centgener plan. Each centgener consisted of a 100-plant plot in which each plant was individually spaced. The original source of seed for each centgener was a single plant or head; similar methods being used for both crosses and selection. In subsequent years ten plants were selected from each plot by inspection in the field and the best five, on the basis of laboratory data, were then used to plant the following year's centgener plot. In winter wheat breeding, winter-killing has been the eliminating factor. That is, when a plot is more severely killed than the rest of the nursery, the type in question is discarded. As only a single plot of 100 plants has been grown yearly, the notes obtained for a particular season are only partially reliable. The method used, however, has served to select the hardier sorts.

Since 1915 these have been tested in replicated rod rows for both yield and hardiness, the more promising sorts being further tested in coöperation with three substations.

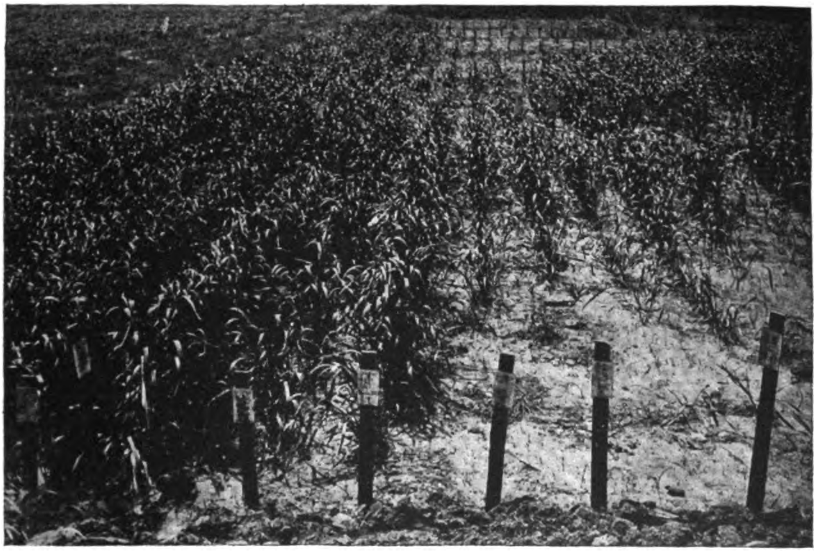

Fig. 4. Odessa, Minn. 1471, Rod Rows, 1918

Three rows at right are Turkey, Minn. 1487; those in the center Odessa, Minn. 1471; and the four border rows are Minn. 1505.

NEW INTRODUCTIONS FROM 1915 TO 1917

In 1915 coöperative arrangements were made with the Office of Cereal Investigations of the United States Department of Agriculture and new introductions of winter wheat or improved varieties are now forwarded to Minnesota in order that we may determine the hardiness of these sorts as a possible basis for further breeding. Acknowledgement is here made of the coöperation of Dr. C. E. Leighty and Mr. J. Allen Clark of that office.

As no sorts thus tested have proved as hardy for our conditions as several of the Minnesota selections and crosses, it would seem that our material is of considerable value as a basis for further winter wheat breeding. The results of the test of the several sorts obtained through the Office of Cereal Investigations are here presented, as they may be of some interest to other workers.

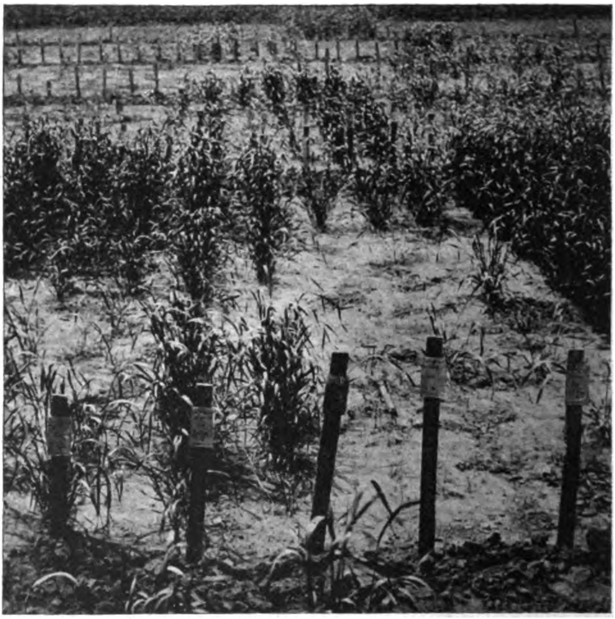

Fig. 5. Turkey × Odessa, Minn. 1507, Rod Rows, 1918

Three rows at left are Turkey × Odessa, Minn. 1507. Three rows at right are Turkey, check, Minn. 1487.

Botanical characters, hardiness, and winter-killing data are given for twenty-eight varieties of Eastern winter wheats which were obtained from Dr. C. E. Leighty. These were grown in plots of three rod rows each in 1917, a standard variety of Turkey, Minnesota 1487, being used as a check and planted every fourth plot. This standard variety was originally obtained from C. N. Cosgrove, Le Sueur, Minnesota, and received the accession number 529. Minnesota 1487 is a pedigreed sort of 529, being the progeny of a single plant. It appears to be about like 529, which is a relatively pure commercial variety. As will be seen in a presentation of hardiness studies, Minnesota accession 529 and Minnesota 1487 are both relatively non-hardy. For this reason they serve as reliable checks, by means of which hardy sorts may be discovered. The Minnesota accession number is not mentioned for these varieties obtained from the Office of Cereal Investigations as it seems that the C. I. number will be of more general interest.

TABLE I

TEST OF EASTERN WINTER WHEATS IN 1917 FOR HARDINESS

Variety	C. I. number	Per cent winter injury	Botanical characters*	
			Plant	Seed color
New Amber Longberry	1973	10	B.H.R.	W., few R.
Michigan Amber	1969	15	A.S.R.	R.
Bearded Winter Fife	1942	5	B.H. A.H.W.	R., W.
Turkey, check	....	0	....	....
Lancaster	1945	15	A.H.R.	R.
Jones Winter Fife	1933	5	A.S.W.	R.
Improved Fultz	1923-1	10	B.S.W.	R.
Turkey, check	....	0	....	....
Cornell Prolific	3326	15	A.S.R.	R., few W.
Early Genessee	1744	40	B.S.R.	W.
Leaps Prolific	not given	70	A.S.W.	R.
Turkey, check	....	5	....	....
Virginia	3277	90	B.H.W.	....
Hybrid	3613	95	B.H.W.	....
Hybrid	3614	95	B.S.R.	....
Turkey, check	....	40	....	....
Hybrid	3612	90	B.S.W.	....
Stoner Nuraree	2980	95	B.S.W.	....
Purple Straw	1957	90	A.S.W.	....
Turkey, check	....	20	....	....
Purple Straw	1915	55	A.S.W.	R.
Dietz Longberry	1981	80	B.S.W.	....
Poole	1979	5	A.S.W.	R.
Turkey, check	....	0	....	....
Hybrid	3608	5	B.S.R.	R.
Bearded Purple Straw	1911	5	B.S.W.	R.
Mammoth Red	2008	15	B.S.W.	R.
Turkey, check	....	0	....	....
Bluestem	1912	0	B.S.R.	R.
Fultz	1923	5	A.S.W.	R., few W.
Martin Amber	1974	2	A.S.W.	R., few W.
Bearded Winter	4204	0	B.H.W.	R., W.
China	180	0	A.S.	R.
Dawson's Golden Chaff	1733	0	A.S.R.	W.
Turkey, check	....	1	....	....
Rocky Mountain	1578	25	B.S.W.	R.

* A—Awnless, B—Bearded, H—Hairy, S—Smooth, R—Red, and W—White.

These varieties were selected by Dr. Leighty as they seemed the most promising for hardiness under eastern conditions. The results given in Table I show that the greater part of these sorts are no hardier than the Turkey variety used as a check. As this Turkey is not very hardy, most of the varieties here reported have been discarded from further test. Bluestem, Bearded Winter, China, and Dawson's Golden Chaff were grown in a replicated plot test in 1917-18 and were again compared with Turkey. The results for the average of two plots appear in Table II.

TABLE II

FURTHER TEST OF EASTERN WINTER WHEATS FOR HARDINESS

Variety	C. I. number	Per cent winter injury
Bluestem	1912	99½
Turkey, check	....	96
Bearded Winter	4204	99
China	180	92
Dawson's Golden Chaff	1733	100
Turkey, check	....	99½

Results in 1918 show that these eastern winter wheat varieties have little or no promise as breeding material for winter hardiness under Minnesota conditions.

Through the coöperation of Mr. Clark two varieties were obtained and planted in the fall of 1917 in three systematically distributed plots. These were Nebraska Hybrid No. 28 and Kanred, Kansas P. 762. They were received under the Office of Cereal Investigations numbers C.I. 5146 and C.I. 5147, respectively. The average winter injury of Kanred was 99 per cent, of Nebraska Hybrid No. 28, 100 per cent, and of the Turkey check 94 per cent. Neither of these sorts appear to be exceptionally hardy under our conditions and they are therefore of little value as a basis for breeding hardier strains. Four selections of a cross between Beloglina C.I. 1543, and Buffum No. 17 C.I. 3330, which were made by Mr. Babcock at Williston, North Dakota, were received from Mr. Clark. Single rows only were grown. All four selections, together with Beloglina, were entirely winter-killed.

Single rows also were tested of Turkey C.I. 1571, Kharkov C.I. 1583, Turkey C.I. 3084, or N. D. No. 1997. All showed 100 per cent winter-killing.

Twelve Montana selections of Kharkov were also tested in 1917-18 in single rod rows. Two or three of these showed some winter hardiness and will be further tested. On the basis of this somewhat limited test, however, none seem as hardy as the better of the Minnesota sorts, which indicates that under Minnesota conditions our strains

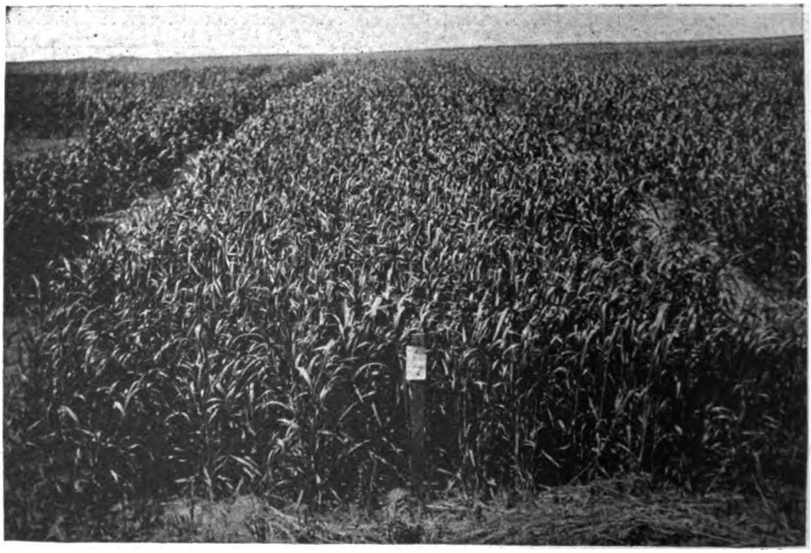

Fig. 6. Odessa, Variety Plots, 1918

excel in winter hardiness. This statement is based upon the fact that Mr. Clark in writing regarding the above introductions said:

"These wheats which I have listed are the only wheats I know of which possess any superior winter hardiness over the ordinary Turkey and Kharkov varieties."

Forty pure-line selections of Turkey were furnished by Mr. L. C. Burnett of the Iowa Agricultural Experiment Station at Ames. On the basis of a two-years' test for hardiness these have been discarded, as they appeared to be less hardy than the better of our Turkey sorts.

RESULTS OF WINTER WHEAT BREEDING

The crosses and selections reported in this paper have been grown in replicated rod-row tests at University Farm for three years, 1916, 1917, and 1918. Some of the more promising have been grown at several of the substations.[4]

General field notes are given in Table III. These are an average of the University Farm 1916 and 1917 data, as there was very little winter injury either of these years.

The number of selections originally made for each Minnesota accession number as well as the number of centgener plots tested for each cross are given in the table, as this gives the reader an idea of how extensive work was carried out in order to find the few hardier strains here reported.

These notes as given are of particular interest as a record of characters of the few hardier sorts. From the standpoint of inter-relation of characters they are of some interest. The statement is often made that soft wheats stand up much better than hard wheats. In our tests the different sorts have been classified for texture of seed by the method previously suggested by the Minnesota Section of the American Society of Agronomy (Hayes, Bailey, Arny, Olson, 1917). In brief, four classes have been used for seed texture: corneous, subcorneous, substarchy, starchy. Except for the durum spring wheats and a few very soft wheats, those tested at this station are classified as either subcorneous or substarchy. Marquis, Bluestem, and Turkey commonly fall in the subcorneous group.

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[4] The planting plan, method of test, threshing, and computing of yields have been cared for by the section of plant breeding of the Central station. Planting, harvesting, and field notes have been cared for by the substations and the section of coöperative seed production and distribution of the Central station. In the winter wheat row tests conducted at the substations, acknowledgement is made of the coöperation of the following persons: C. P. Bull and August Haedecke of the section of coöperative seed production and distribution; P. E. Miller and Theodore Odland, of the Morris substation; O. I. Bergh, of the Grand Rapids substation; and Albert Hoversten of the Waseca substation. For the spring wheat and oat tests reported, we are indebted to the section of coöperative seed production and distribution; Albert Hoversten of the Waseca substation; P. E. Miller and Theodore Odland of the Morris substation; and C. G. Selvig and Roy Westley of the Crookston substation.

TABLE III

BOTANICAL AND FIELD NOTES OF WINTER WHEAT. AVERAGE RESULTS 1916 AND 1917 ROW TEST. UNIVERSITY FARM

Name	N. S. N.	Minn. Acces. No.	Average height, inches	Average per cent lodging	Average degree lodging	Botanical head characters	Date heading 1917	Seed texture*	No. original centgener selections
Turkey†	I-99-1	323	36	77	55	B.S.W.	6/27	SC.	15
Odessa	I-01-3	558(1471)	45	19	4	A.S.R.	6/30	SS.	5
Crimean Group	I-02-27	550	42	95	60	B.S.W.	6/26	SC.	50
Ghirka Winter	I-02-71	833(1473)	41	99	64	A.S.W.	6/24	SC.	11
Crimean Group	I-02-102	836(1474)	39	95	60	B.S.W.	6/23	SC.	18
Turkey	I-03-120	638(1488)	38	98	67	B.S.W.	6/24	SC.	40
Turkey	I-03-213	829	36	100	60	B.S.W.	6/26	SC.	40
Padui	I-03-229	835(1491)	40	63	19	B.S.R.	6/27	SC.	16
Crimean Group	I-04-59	918(1479)	36	100	75	B.S.W.	6/21	SC.	10
Big Frame	I-06-6	960(1481)	40	99	61	A.S.W.	6/28	SS.	1
Odessa	I-15-7	1176	44	74	34	A.S.R.	6/26	S.	7
Odessa	I-15-12	1176	42	60	60	B.S.W.	6/24	SC.-C.	7
Poole	I-15-20	561	41	100	51	A.S.R.	6/25	SS.	10
Harv. King	I-15-26	643	44	54	42	A.S.R.	6/26	SS.-S.	11
Harv. King	I-15-29	643	44	55	43	A.S.R.	6/27	SS.	11
Harv. King	I-15-33	643	45	70	41	A.S.R.	6/25	SS.-S.	11
Crimean Group	I-15-36	832	44	50	23	B.S.W.	6/28	SS.-SC.	7
Crimean Group	I-15-134	1051	45	90	67	B.S.W.	6/26	SS.	16
Crimean Group	I-15-155	918	44	55	50	B.S.W.	6/26	SC.	8
Odessa	I-15-177	558	47	3	5	A.S.R.	6/29	SS.	19
Odessa	I-15-179	558	46	9	14	A.S.R.	6/29	SS.	..
Odessa	I-15-190	558	47	13	2	A.S.R.	6/30	SS.-SC.	19
Crimean Group	III-16	845	41	75	48	B.S.W.	6/24	SC.	19
Turkey × Odessa	II-02-259	829 × 642(1506)	40	35	5	A.S.W.	6/27	SS.	88
Turkey × Odessa	II-02-280	829 × 642(1507)	41	74	46	B.S.W.	6/23	SS.-SC.	..
Turkey × Odessa	II-02-14	829 × 558(1493)	40	96	66	A.S.R.	6/27	SC.	93
Turkey × Odessa	II-02-195	829 × 558(1505)	41	57	50	A.S.W.	6/25	SS.	..
Turkey × Odessa	II-02-190	829 × 558	40	57	35	A.S.W.	6/27	SS.-SC.	..
Turkey × Odessa	II-02-81	558 × 829	42	62	38	B.S.R.	6/25	SC.-C.	79
Turkey × Odessa	II-02-502	558 × 829	40	60	55	A.S.R.	6/26	SS.	..
Odessa × Turkey	II-02-41	642 × 829(1497)	40	92	55	B.S.R.	6/25	SC.	60
Odessa × Turkey	II-02-67	558 × 829(1498)	41	56	34	B.S.W.	6/26	SS.	..
Odessa × Turkey	II-02-334	642 × 829(1509)	37	64	45	B.S.W.	6/30	SS.	..
Odessa × Turkey	II-02-30	642 × 829(1496)	42	50	29	B.S.W.	6/28	SS.-SC.	..
Odessa × Turkey	II-01-7	558 × 323(1484)	41	64	37	B.S.R.	6/28	SS.	5
Odessa × Turkey	II-02-22	642 × 829	40	79	49	A.S.R.	6/30	SS.-SC.	..

TABLE III—*Continued*

BOTANICAL AND FIELD NOTES OF WINTER WHEAT. AVERAGE RESULTS 1916 AND 1917 ROW TEST. UNIVERSITY FARM

Name	N. S. N.	Minn. No.	Average height, inches	Average per cent lodging	Average degree lodging	Botanical head characters	Date heading 1917	Seed texture*	No. original centgener selections
Odessa×Turkey	II-02-21	642×829	38	100	50	A.S.R.	6/27	SC.	..
Odessa×Turkey	II-02-333	642×829	37	98	54	B.S.W.	6/27	SS.-SC.	..
Turkey×Khar.	II-02-115	823×829	38	93	56	A.S.R.	6/25	SC.	9
Turkey×Khar.	II-02-382	829×836	39	69	39	B.S.W.	6/26	SS.	26
Turkey×C. G.	II-02-144	829×550	37	89	46	B.S.W.	6/20	SS.-SC.	80
Turkey×C. G.	II-02-181	829×550	39	67	50	A.S.R.	6/27	SC.	..
Turkey×C. G.	II-02-620	829×550	38	100	57	A.S.W.	6/29	SS.	..
Turkey×C. G.	II-02-618	829×550	41	70	45	A.S.W.	6/29	SS.	..
(?)×Turkey	II-02-519	552×829	43	41	10	B.S.W.	6/28	SC.	26
(?)×Turkey	II-02-521	552×829	40	63	53	B.S.W.	6/25	C.	..
Turkey×(?)	II-02-129	829×837	41	84	67	A.S.R.	6/26	SS.	74
Turkey×(?)	II-02-648	829×552	40	72	59	A.S.R.	6/28	SS.-SC.	26
Turkey×(?)	II-02-683	829×837	41	70	54	B.S.R.	6/26	SS.-SC.	..
Turkey×(?)	II-02-127	829×837	40	72	45	B.S.R.	6/26	SS.	..
J. Long.×C. G.	II-06-4	839×550	40	68	45	B.S.R.	6/26	SS.	5
J. Long.×Turkey	II-06-131	839×943	39	99	69	B.S.R.	6/23	SS.-SC.	..
Turkey×Poole	II-06-15	943×561	39	89	62	B.S.W.	6/24	SC.	..
Turkey×Poole	II-06-17	529×576	41	59	53	A.S.W.	6/25	SS.	..
Turkey×Harv. King	II-06-60	529×841	39	69	50	B.S.W.	6/25	SC.	..
Big Frame×Turkey	II-06-125	960×529	40	96	44	B.S.W.	6/21	SC.	..
Winter×Spring	II-08-70	829/552×165	42	50	29	A.S.W.	6/27	SC.	..
Winter×Spring	II-08-13	529×169/280	39	72	62	B.S.R.	6/25	SS.	..
Winter×Spring	II-08-81	558×1006	40	70	59	B.S.R.	6/23	SC.-C.	..
Check	Check	1487	39	95	58	B.S.W.	6/22	SC.	88

* C., Corneous; SC., subcorneous; SS., substarchy; S., Starchy.

† These pure lines have been classified by J. A. Clark of the Office of Cereal Investigations, U. S. Dept. of Agr.

Among the pure lines the four Odessa selections, I-01-3, I-15-179, I-15-177, and I-15-190, which have substarchy seed, seem more resistant to lodging than the Turkey sorts. On the other hand, Big Frame, I-06-6, which is also a starchy wheat, lodges very badly.

Notes on lodging are taken by estimating the percentage of the plot which deviates from the normal or upright habit, i.e., the percentage lodged, and the angle which the lodged plant makes with the normal, or the degree lodged; 90 degrees being considered flat. As notes are taken for three systematically distributed plots, they are fairly reliable. These notes are taken at maturity.

From the results of some of the crosses it seems reasonable to conclude that subcorneous seeded types can be produced which stand up much better than the ordinary Turkey sorts. As an example II-02-519 may be cited. This gave a good yield at University Farm as determined by the three years' test and lodged only very slightly. II-02-81, a cross between Turkey and Odessa, is another example of a subcorneous wheat which stands up well. Both of these are bearded sorts.

The result of the Turkey-Odessa crosses indicate what may be obtained from parents which differ in time of maturity. Of the fifteen crosses between Turkey and Odessa appearing in the table, some head as early as the more early Turkey sorts while others are as late in maturity as the Odessa parent. For example, Odessa headed June 30. Of the fifteen crosses mentioned, two headed June 30, two June 28,

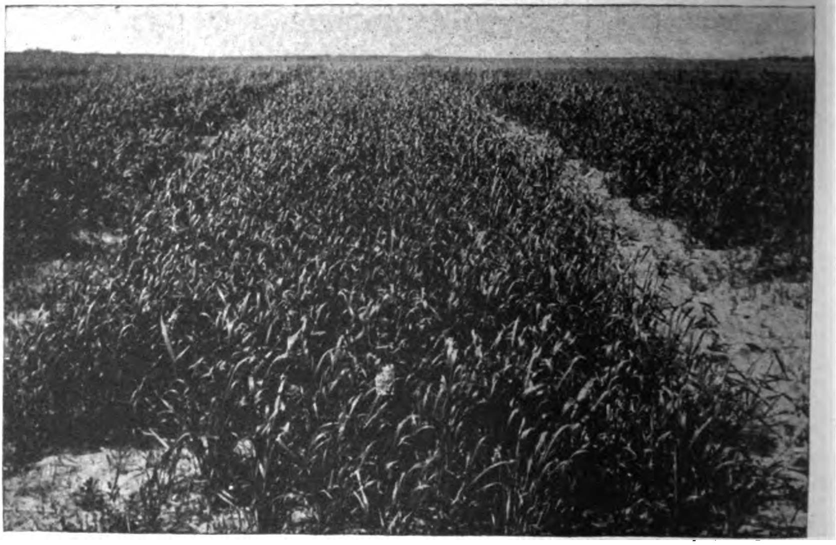

Fig. 7. Turkey X Odessa, Minn. 1505, Variety Plots, 1918

one June 23, and the rest on intermediate dates. An examination of these varieties as grown in our row tests would, we believe, convince any agronomist that these crosses are comparatively pure for time of maturity.

Data on hardiness for the pure lines and crosses are given in Table IV. Averages are given in the table for the results at University Farm in 1917 and at Grand Rapids in 1916 and 1917, also for the winter injury at University Farm and Waseca in 1918, and at Grand Rapids in 1917 and 1918. The latter average is the more reliable, as it is from tests in which winter injury was most severe.

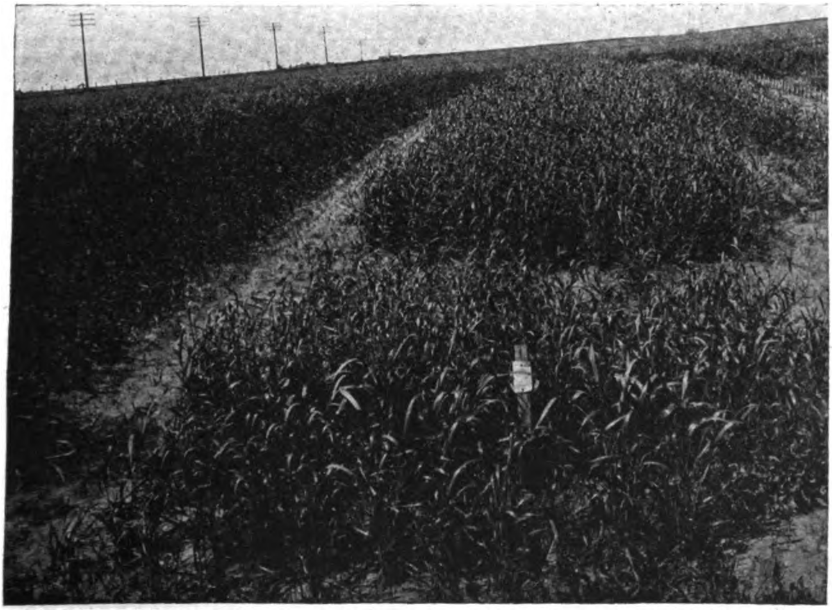

Fig. 8. Turkey × Odessa, Minn. 1507, Variety Plots, 1918

Of the pure lines which excel in hardiness, Odessa I-01-3 and Big Frame I-06-6, which have been tested all years at all stations, are the most promising of the substarchy, awnless sorts. Two subcorneous wheats, I-03-120, a Turkey selection, and I-03-229, excel in hardiness. The latter sort is the result of a head selection which was made from a Russian winter wheat introduction from the vicinity of Padui. It has been called Padui in our studies. Crimean, Minnesota accession 845, is a commercial sort which has also given a good record as a hardy variety.

TABLE IV

HARDINESS STUDIES OF PURE LINES AND CROSSES IN WINTER WHEAT

(Replicated Rod Row Tests)

Name	N. S. N.	Minn. Access. No.	Percentage winter-killed							
			Univ. Farm		Grand Rapids			Waseca	Average Univ. Farm, 1917 Grand Rapids, 1916-17	Average Univ. Farm, Waseca, 1918 Grand Rapids, 1917-18
			1917	1918	1916	1917	1918	1918		
Turkey	I-99-1	323	33	99	......	97	58	58	......	78
Odessa	I-01-3	558(1471)	40	65	10	33	37	18	28	38
Crimean Group	I-02-27	550	0	95	26	55	32	45	27	57
Ghirka Winter	I-02-71	833(1473)	5	96	35	89	52	53	43	73
Crimean Group	I-02-102	836(1474)	7	98	23	51	56	49	27	64
Turkey	1-03-120	638(1488)	3	91	16	30	18	20	18	40
Turkey	I-03-213	829	25	96	......	34	36	39	......	51
Padui	I-03-229	835(1491)	4	58	3	20	5	31	9	26
Crimean Group	I-04-59	918(1749)	10	94	10	74	27	57	31	63
Big Frame	I-06-6	960(1481)	3	47	10	23	1	32	12	26
Odessa	I-15-7	1176	0	75	......	27	6	34	......	36
Odessa	I-15-12	1176	7	92	......	23	34	60	......	52
Poole	I-15-20	561	5	93	......	......	......	......	......	......
Harv. King	I-15-26	643	0	91	......	31	18	56	......	49
Harv. King	I-15-29	643	1	86	......	......	......	......	......	......
Harv. King	I-15-33	643	0	86	......	......	......	......	......	......
Crimean Group	I-15-36	832	5	72	......	30	1	51	......	39
Crimean Group	I-15-134	1051	0	79	......	24	1	42	......	37
Crimean Group	I-15-155	918	0	92	......	......	......	......	......	......
Odessa	I-15-177	558	5	80	......	......	......	......	......	......
Odessa	I-15-179	558	0	75	......	......	......	......	......	......
Odessa	I-15-190	558	0	76	......	......	1	44	......	......
Crimean Group	III-16	845	20	51	11	49	20	27	27	37
Turkey × Odessa	II-02-259	829 × 642(1506)	2	63	2	51	2	37	18	38
Turkey × Odessa	II-02-280	829 × 642(1507)	5	67	12	47	3	52	36	42
Turkey × Odessa	II-02-14	829 × 558(1493)	0	75	2	50	14	51	17	48
Turkey × Odessa	II-02-195	829 × 558(1505)	2	33	42	36	15	32	14	29
Turkey × Odessa	II-02-190	829 × 558	2	83	......	20	......	......	......	......
Turkey × Odessa	II-02-81	558 × 829	3	82	......	......	......	......	......	......
Turkey × Odessa	II-02-502	558 × 829	2	89	......	......	......	......	......	......
Odessa × Turkey	II-02-41	642 × 829(1497)	7	62	3	20	11	48	10	35
Odessa × Turkey	II-02-67	558 × 829(1498)	1	82	7	22	9	59	10	43
Odessa × Turkey	II-02-334	642 × 829(1509)	1	73	8	42	7	52	17	44
Odessa × Turkey	II-02-30	642 × 829(1496)	14	40	8	30	7	46	17	31
Odessa × Turkey	II-01-7	558 × 323(1484)	12	62	3	32	13	53	16	40
Odessa × Turkey	II-02-22	642 × 829	10	......	7	48	......	......	22	......

TABLE IV—*Continued*

HARDINESS STUDIES OF PURE LINES AND CROSSES IN WINTER WHEAT
(Replicated Rod Row Tests)

Name	N. S. N.	Minn. Access. No.	Percentage winter-killed							
			Univ. Farm		Grand Rapids			Waseca	Average Univ. Farm, 1917 Grand Rapids, 1916-17	Average Univ. Farm, Waseca, 1918 Grand Rapids, 1917-18
			1917	1918	1916	1917	1918	1918		
Odessa × Turkey	II-02-21	642 × 829	17	......	12	53	......	......	27	......
Odessa × Turkey	II-02-333	642 × 829	1	......	12	39	......	......	17	......
Turkey × Khar.	II-02-115	823 × 829	8	......	8	45	......	......	20	......
Turkey × Khar.	II-02-382	829 × 836	3	......	5	44	......	......	17	......
Turkey × C. G.	II-02-144	829 × 550	3	91	......	......	......	......	......	......
Turkey × C. G.	II-02-181	829 × 550	2	82	3	31	9	67	23	47
Turkey × C. G.	II-02-620	829 × 550	1	77	......	......	......	......	......	......
Turkey × C. G.	II-02-618	829 × 550	1	68	......	......	......	......	......	......
(?) × Turkey	II-02-519	552 × 829	5	69	......	......	......	......	......	......
(?) × Turkey	II-02-521	552 × 829	1	81	......	39	12	81	......	53
Turkey × (?)	II-02-129	829 × 837	3	97	......	......	......	......	......	......
Turkey × (?)	II-02-648	829 × 552	7	98	......	......	......	......	......	......
Turkey × (?)	II-02-683	829 × 837	3	82	......	......	......	......	......	......
Turkey × (?)	II-02-127	829 × 837	2	......	2	......	......	......	......	......
J. Long × C. G.	II-06-4	839 × 550	1	71	......	......	......	......	......	......
J. Long × T.	II-06-131	839 × 943	5	96	......	......	......	......	......	......
Turkey × Poole	II-06-15	943 × 561	3	77	......	......	......	......	......	......
Turkey × Poole	II-06-17	529 × 576	2	87	......	......	......	......	......	......
Turkey × H. K.	II-06-60	529 × 841	5	95	......	......	......	......	......	......
Big Frame × T.	II-06-125	960 × 529	0	97	......	......	......	......	......	......
Winter × Spring	II-08-70	829/552 × 165	5	92	......	......	......	......	......	......
Winter × Spring	II-08-73	529 × 169/280	2	99	......	......	......	......	......	......
Winter × Spring	II-08-81	558 × 1006	4	99	......	......	......	......	......	......
Check	Check	529(1487)	4	94	23	66	62	71	31	73

The most extensive tests of any of the crosses are those between various Turkeys and Odessa. Of the two Odessa sorts, accession 558 is still being grown at University Farm. Accession 642 was discarded in 1904, as it appeared to be less hardy than 558. All of the Turkey sorts used as parents of these crosses were lacking in hardiness as compared with selection I-03-120 and Minnesota accession 845, which is one of the best Crimean wheats tested in the plot variety test.

The crosses which are here presented for hardiness comprise fifteen selections out of a total of 325 centgener selections which were grown for a considerable number of years. Of these fifteen crosses, II-02-195, which has been given the Minnesota number 1505, is the most hardy. It is an awnless wheat with a short head and white chaff. The seeds are similar in shape to the common fife spring wheat altho they are somewhat softer. The lowest winter injury of the Turkey check for any of the four years which are used as the basis of the final average percentage of winter injury data in the table, was 62 per cent, which was obtained at Grand Rapids in 1918. II-02-195 has a continuous record of little winter injury as determined by all tests.

Of the Odessa-Turkey crosses, II-02-280 resembles Turkey in field type of plant and shape of seed. It is slightly softer than some Crimean selections but more corneous than II-02-195.

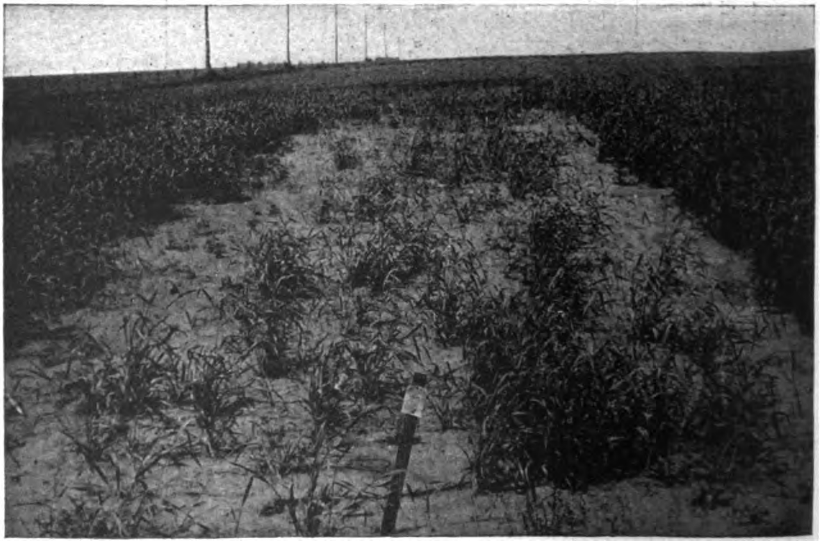

Fig. 9. Turkey, Minn. Accession No. 529, Variety Plots, 1918

These crosses show all sorts of recombinations of the characters of the parental sorts, some being very hardy, others intermediate, while others lack winter hardiness. Data of this sort corroborate the observations of Nilsson-Ehle (loc. cit.) and show that winter wheat hardiness is due to the interaction of numerous inherited factors.

Altho many other crosses have been studied, none have given types which are as hardy as the Odessa-Turkey sorts. This shows the necessity of making a careful study of the hardiness of the parent sorts before making extensive crosses.

The results of the yield tests are presented in Table V for each crop year and locality. Averages are given for the University Farm tests and also for all tests at all localities. These tests show that the types which excel in hardiness generally excel in yield. Turkey × Odessa, Minnesota 1505, for example, is the most hardy wheat grown. It gave the highest average yield, both at University Farm and as determined by all tests which comprise the results of the test for three crop seasons at University Farm, three at Grand Rapids, and one at Waseca. The yields at Grand Rapids have been low for all years regardless of the winter injury or the variety. These Grand Rapids tests are chiefly valuable in a determination of hardiness. Thus in 1918 the Grand Rapids rows were seriously injured by dry weather, this being the cause of the low yields rather than winter injury.

The yields of some of these better sorts are very striking as compared with the check plots which gave an average yield of 23.9 bushels at University Farm for the three years and 17.7 bushels for all tests. Turkey × Odessa II-02-195 gave an average yield at University Farm of 40.3 bushels and of 27 bushels as determined by all tests, while the Odessa parent averaged 31.3 bushels at University Farm and 22.6 bushels for all tests.

Other promising sorts are Turkey I-03-120, with an average yield at University Farm of 36.9 bushels and at all stations of 26.3 bushels; and II-02-280 Turkey × Odessa, which is a high yielding sort but somewhat less hardy than II-02-195.

On a basis of the yield and hardiness test the following seem worth while testing in field plots at all stations. Summarized data are here given.

Variety	N. S. N.	Minn. No.	Average yield U. Farm 1916-18 Waseca 1918	Average winter injury
			Bushels	Per cent
Odessa	I-01-3	1471	31.1	38
Turkey	I-03-120	1488	36.8	40
Turkey × Odessa	II-02-195	1505*	39.1	29
Turkey × Odessa	II-02-280	1507*	34.9	42
(?) × Turkey	II-02-519	....	38.7†	....
Crimean	....	845	30.6	37
Turkey	Check	1487	23.0	73

* The Experiment Station has decided to increase and distribute two crosses between Turkey × Odessa. These sorts have been named Minhardi, Minn. 1505; and Minturki, Minn. 1507.

† University Farm tests only.

TABLE V

Yields of Winter Wheat at University Farm and Substations, Row Test, 1916-1918

Name	N. S. N.	University Farm			Grand Rapids			Waseca	Aver. U. Farm	Average all stations all years
		1916	1917	1918	1916	1917	1918	1918	1916-1918	
		Bushels	Bushels	Bushels	Bushels	Bushels	Bushels	Bushels	Bushels	Bushels
Turkey	I-99-1	25.6	33.7	....	....	7.1	1.4	22.3	19.8	....
Odessa	I-01-3	32.9	36.1	24.8	20.7	10.4	2.8	30.6	31.3	22.6
Crimean Group	I-02-27	35.9	40.7	11.3	10.6	9.3	3.8	24.9	29.3	19.5
Ghirka Winter	I-02-71	31.6	31.4	11.8	20.2	10.1	5.0	18.6	22.9	18.4
Crimean Group	I-02-102	32.0	36.2	7.9	17.1	3.4	6.8	25.3	25.4	18.4
Turkey	I-03-120	33.4	40.9	36.5	16.2	13.8	7.0	36.4	36.9	26.3
Turkey	I-03-213	24.7	30.0	7.7	....	11.8	3.1	40.1	20.8	....
Padui	I-03-229	27.0	42.5	23.9	19.4	8.2	2.7	21.1	31.1	20.7
Crimean Group	I-04-59	28.9	35.8	5.0	26.0	5.4	9.2	23.4	23.2	19.1
Big Frame	I-06-6	28.9	39.1	30.7	19.7	14.4	2.0	25.5	....	22.9
Odessa	I-15-7	36.9	49.2	25.5	....	12.8	4.1	25.5	37.2	....
Odessa	I-15-12	32.7*	39.9	9.6	....	16.0	3.0	32.9	27.4	....
Poole	I-15-20	31.6*	42.7	18.0	....	....	....	....	30.8	....
Harvest King	I-15-26	28.5	39.8	14.6	....	8.7	8.0	16.4	27.6	....
Harvest King	I-15-29	33.8*	46.4	20.2	....	....	....	....	33.5	....
Harvest King	I-15-33	31.8*	48.3	22.2	....	....	....	....	34.1	....
Crimean Group	I-15-36	28.6†	41.7	24.7	....	7.5	5.0	20.8	31.7	....
Crimean Group	I-15-134	25.4*	39.9	22.3	....	8.7	4.5	24.3	29.2	....
Crimean Group	I-15-155	31.6†	43.1	16.2	....	....	....	....	30.3	....
Odessa	I-15-177	29.0†	45.6	discard	....	....	....	....	....	....
Odessa	I-15-179	28.7†	47.3	discard	....	....	....	....	....	....
Odessa	I-15-190	30.0†	42.6	discard	....	....	6.5	16.7	....	....
Crimean Group	III-16	30.6	36.9	17.8	22.3	13.7	5.6	37.2	28.4	23.4
Turkey × Odessa	II-02-259	29.3	39.0	23.9	19.6	7.7	3.7	35.6	30.7	22.7
Turkey × Odessa	II-02-280	38.7	47.5	20.9	26.8	8.4	6.6	32.5	35.7	25.9
Turkey × Odessa	II-02-14	28.3	33.8	18.1	23.9	10.1	4.4	23.6	26.7	20.3
Turkey × Odessa	II-02-195	37.0	43.1	40.9	18.8	10.0	4.0	35.3	40.3	27.0
Turkey × Odessa	II-02-190	30.0	39.6	23.6	....	....	....	....	31.1	....
Turkey × Odessa	II-02-81	36.0	41.5	23.4	24.7	11.6	....	....	33.6	....
Turkey × Odessa	II-02-502	34.9	41.6	20.9	....	....	....	....	32.5	....
Odessa × Turkey	II-02-41	28.7	35.1	21.0	25.1	11.1	5.0	28.3	28.3	....
Odessa × Turkey	II-02-67	33.6	43.1	20.5	17.3	11.4	7.3	20.1	32.4	21.9
Odessa × Turkey	II-02-334	34.6	34.7	22.0	18.1	11.1	5.3	21.6	30.4	21.1
Odessa × Turkey	II-02-30	35.3	37.1	37.0	17.1	8.7	5.3	23.7	36.5	23.5
Odessa × Turkey	II-01-7	31.0	36.5	29.4	17.5	10.9	9.1	16.1	32.3	21.5
Odessa × Turkey	II-02-22	30.4	33.3	....	16.1	6.6	....	....	....	....
Odessa × Turkey	II-02-21	32.0	30.9	....	19.5	5.1	....	....	....	....

TABLE V—*Continued*

YIELDS OF WINTER WHEAT AT UNIVERSITY FARM AND SUBSTATIONS, ROW TEST, 1916-1918

Name	N. S. N.	University Farm			Grand Rapids			Waseca	Aver. U. Farm	Average all stations all years
		1916	1917	1918	1916	1917	1918	1918	1916-1918	
		Bushels	Bushels	Bushels	Bushels	Bushels	Bushels	Bushels	Bushels	Bushels
Odessa × Turkey	II-02-333	32.1	37.4	....	18.4	10.2	....	....	....	....
Turkey × Kharkov	II-02-115	30.7	34.2	....	24.1	5.1	....	....	....	....
Turkey × Kharkov	II-02-382	35.5	44.6	....	23.4	7.3	....	....	....	....
Turkey × Crimean Group	II-02-144	34.3	42.2	discard	....	....	....	....	....	....
Turkey × Crimean Group	II-02-181	25.4	38.1	discard	....	....	4.1	17.0	....	....
Turkey × Crimean Group	II-02-620	26.5	40.3	32.8	....	....	....	....	33.2	....
Turkey × Crimean Group	II-02-618	28.3	31.5	33.5	....	....	....	....	31.1	....
(?) × Turkey	II-02-519	35.3	43.1	37.8	....	....	....	....	38.7	....
(?) × Turkey	II-02-521	33.2	44.2	20.8	....	10.3	3.3	15.0	32.7	....
Turkey × (?)	II-02-129	30.7	40.5	9.5	....	....	....	....	26.9	....
Turkey × (?)	II-02-648	29.4	43.1	18.9	....	....	....	....	30.5	....
Turkey × (?)	II-02-683	36.1	38.7	20.9	....	....	4.0	33.6	31.9	....
Turkey × (?)	II-02-127	27.1	39.1	9.5	26.0	7.2	....	....	25.2	....
J. Longberry × Crim. Gr.	II-06-4	30.0	45.9	discard	....	....	....	....	....	....
J. Longberry × Turkey	II-06-131	26.4	37.9	discard	....	....	....	....	....	....
Turkey × Poole	II-06-15	32.7	44.6	24.4	....	....	....	....	33.9	....
Turkey × Poole	II-06-17	29.2	42.9	15.6	....	....	....	....	29.2	....
Turkey × Harvest King	II-06-60	30.7	39.2	7.1	....	....	....	....	25.8	....
Big Frame × Turkey	II-06-125	37.2	46.6	discard	....	....	7.7	18.8	....	....
Winter × Spring	II-08-70	27.3	39.2	20.0	....	....	....	....	28.8	....
Winter × Spring	II-08-13	29.3	34.7	discard	....	....	....	....	....	....
Winter × Spring	II-08-81	32.3	40.4	discard	....	....	....	....	....	....
Turkey	Check	27.5	39.0	5.3	20.9	7.7	3.2	20.2	23.9	17.7

* Single-plot test.   † Two-plot test.

On a basis of the comparison here given, some of these pedigreed sorts seem very promising. For example, II-02-195 yields 70 per cent more bushels per acre on the basis of this test than the variety which has been commonly grown and 28 per cent more than one of the best commercial Crimean sorts tested in the nursery. II-02-280 is also a high yielder and is of the Turkey type.

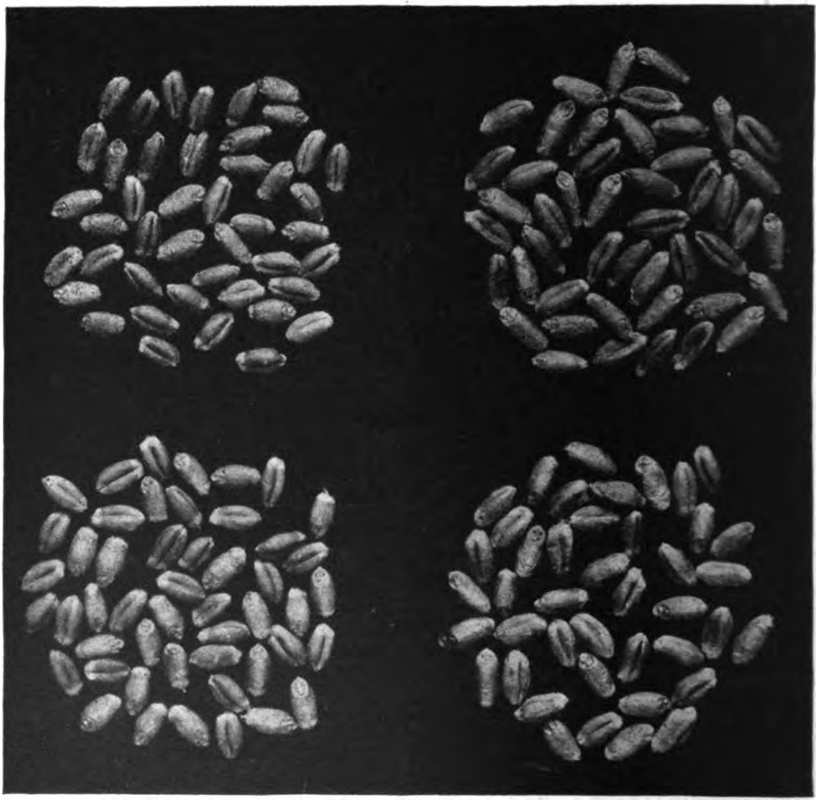

Fig. 10. Typical Seed of Crosses and Parents

Below, from left to right, Odessa, Minn. 1471; Turkey, Minn. 1487. Above, from left to right, Turkey × Odessa, Minn. 1505; and Turkey × Odessa, Minn. 1507. The seed of Minn. 1505 are the shape of Odessa, while those of Minn. 1507 are the shape of Turkey winter wheat.

SPRING WHEAT

A survey of the problems to be solved by the plant breeder for wheat indicated that in Minnesota there were two main needs. One of these, hardier winter wheat, has already been discussed and results have been presented. For the spring wheat group the most apparent need seemed to be a rust-resistant wheat of the *Triticum vulgare* species. As there seemed to be good evidence that the form which was supposed to be the cause of rust in Minnesota, *Puccinia graminis tritici,* was stable in its parasitic relation to certain wheat hosts (Stakman, Piemeisel, and Levine, 1918), the problem was attacked with the belief that solving it was only a matter of time.[5] Added impetus to the work was given with the knowledge that Kanred was rust resistant. It seemed a simple problem to combine the rust resistance of this winter wheat with the characters of such a wheat as Marquis.

Breeding, therefore, for yield and quality was under way in connection with this rust investigation. This naturally limited other spring wheat breeding studies and for this reason only tests of selections made many years ago, a few recent ones, and purified forms from several crosses are reported here. It may not be out of place to mention that several biologic forms of the black stem rust have been recently discovered which can be surely differentiated only by their reaction to pure lines of wheat. This knowledge limits further breeding for rust resistance and also places the breeding for yield and quality on a somewhat different basis. If there are many forms of stem rust, the number at present being somewhat problematical, it seems that until more information is available the breeder should endeavor to produce early maturing sorts of high yield and quality and await further pathological investigations before attempting to solve the rust problem by breeding.

ROW TESTS OF BREAD WHEAT SORTS

The production of Marquis[6] wheat has been of much economic value for the greater part of the Northwest and in the opinion of the writers it alone more than justifies the expenditure of all the money used in wheat-breeding investigations both in the United States and Canada. Because of the widespread adaptation of this variety as shown by yielding ability and quality (Arny, 1914) (Bailey, 1914) (Ball and Clark, 1916), there appears to be no very pressing need of a variety to supersede Marquis.

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[5] **Coöperative work between the Division of Plant Pathology and Botany, the Office of Cereal Investigations, and the Section of Plant Breeding.**

[6] **Selection from a cross between Red Fife and Hard Red Calcutta made by Dr. A. P. Saunders in 1892.**

TABLE VI

Yields in Bushels per Acre of Spring Wheat in Rod Row Tests, 1916, 1917, 1918

Variety	N. S. N.	Minn. Acces. No.	University Farm				Crookston				Morris				Waseca	Grand average	1918 average
			1916	1917	1918	Avg.	1916	1917	1918	Avg.	1916	1917	1918	Avg.	1918		
Speltz Marz (durum)	I-00-45	337	22.5	41.4	27.9	30.6	18.0	27.8	44.2	30.0	11.3	32.2	28.8	24.1	34.6	28.9	33.9
Mindum (durum)	I-00-52	470	23.1	45.2	31.6	33.3	24.0	27.5	57.7	36.4	14.2	33.1	32.4	26.6	35.7	32.5	39.4
Acme (durum)	III-17	....	......	37.2	21.7	......	......	19.5†	46.2	......	......	30.5†	32.3	......	24.9	....	31.3
D-1 (durum)	III-17	....	......	33.3*	21.5	......	......	......	41.8	......	......	33.3*	29.6	......	25.1	....	29.5
D-5 (durum)	III-17	....	......	36.1	22.9	......	......	......	42.1	......	......	......	30.8	......	23.7	....	29.9
Kubanka 2094 (durum)	III-17	....	......	37.6*	22.6	......	......	......	52.0	......	......	......	31.0	......	27.8	....	33.4
Emmer	I-13-4	....	......	42.1†	32.3	......	......	......	......	......	......	......	......	......	....	....	....
Marquis	III-13	1240	15.3	39.6	30.1	28.3	4.4	19.7	46.6	23.8	5.5	30.8	25.3	20.5	32.6	24.5	33.7
Marquis	I-15-165	1369	19.1*	39.2†	25.4	27.9	......	16.4†	39.3	......	......	27.1	25.8	......	39.9	....	32.6
Marquis	I-15-178	1239	16.7†	44.0	24.1	28.3	......	......	43.0	......	......	......	28.0	......	37.2	....	32.4
Marquis	I-15-177	1239	16.8†	42.5	30.6	30.0	......	......	......	......	......	......	......	......	....	....	....
Marquis	I-16-54	1239	......	47.1*	30.6	......	......	......	41.0	......	......	......	29.1	......	32.1	....	33.2
Marquis	I-16-64	1239	......	44.6*	33.6	......	......	......	......	......	......	......	......	......	....	....	....
Marquis	I-16-77	1239	......	46.7*	36.5	......	......	......	......	......	......	......	......	......	....	....	....
Marquis	I-16-81	1239	......	44.1*	33.8	......	......	......	......	......	......	......	......	......	....	....	....
Marquis	I-16-86	1239	......	49.2*	31.8	......	......	......	......	......	......	......	......	......	....	....	....
Marquis	I-16-93	1239	......	44.4*	27.4	......	......	......	......	......	......	......	......	......	....	....	....
Velvet Chaff	III-17	1011	......	37.0†	35.1	......	......	17.6†	......	......	......	29.1†	......	......	....	....	....
Velvet Chaff	I-15-151	1011	18.5†	39.0	28.7	28.7	......	14.4	39.4	......	......	31.9	24.8	......	32.7	....	31.4
Velvet Chaff	I-15-158	1011	16.8†	41.0	29.3	29.0	......	16.7	......	......	......	28.5	......	......	....	....	....
Velvet Chaff	I-15-161	1011	17.7†	41.4	27.5	28.9	......	......	......	......	......	......	......	......	....	....	....
Preston	III-17	924	......	39.6†	32.3	......	......	19.2†	......	......	......	30.6†	......	......	....	....	....
Preston	II-06-39	188×188	17.2	37.0	28.0	27.4	7.3	23.7	43.3	24.8	5.9	30.1	22.1	19.4	39.8	25.4	33.3
Barletta	I-13-41	1178	20.2	43.4*	31.2	31.6	2.2	......	......	......	3.8	......	......	......	....	....	....
Poultofka	1-13-3	1164	16.5	40.5	32.5	29.8	5.5	21.8	46.7	24.7	4.2	36.0	22.8	21.0	32.6	....	33.7
B.B.S.×Preston	II-06-9	146×188	16.4	35.1	30.3	27.3	4.5	20.0	39.6	21.4	5.8	30.4	24.6	20.3	32.9	....	31.9
Winter×Van Vorsts	II-07-15	829×1006 836	......	40.6*	35.9	......	......	......	......	......	......	......	......	......	....	....	....
Winter×Well. Fife	II-07-31	829×165 552	15.2	39.8†	30.5	28.5	......	......	......	......	......	......	......	......	....	....	....
Turkey×Well. Fife	II-08-17	578×165	21.6	37.3†	37.4	32.1	6.8	33.4*	32.0	24.1	4.9	33.6*	20.8	19.8	29.0	25.7	29.8
Turkey×Well. Fife	II-08-19	578×165	19.8	40.1	31.8	30.6	......	......	37.7	......	......	......	22.1	......	29.9	....	30.4
Turkey×Well. Fife	II-08-21	578×165	17.1	36.5†	32.7	28.8	4.6	13.2	39.1	19.0	6.0	32.5	22.4	20.3	30.1	....	31.1
Turkey×Well. Fife	II-08-26	578×165	19.3	37.9	34.6	28.5	3.4	17.7	35.0	18.7	6.0	30.9	22.7	19.9	30.7	23.8	30.8
Turkey×Well. Fife	II-08-27	578×165	19.2	34.3†	32.1	28.5	5.6	25.3	38.5	23.1	8.4	31.7	27.6	22.6	28.5	....	31.7
Turkey×Well. Fife	II-08-29	578×165	18.1	......	32.7	......	2.6	20.9	......	......	8.3	30.7	......	......	....	....	....
Turkey×Well. Fife	II-08-32	578×165	15.0	......	35.2	......	......	......	......	......	......	......	......	......	....	....	....
Turkey×Well. Fife	II-08-40	578×165	16.4	39.4	41.0	32.3	......	......	......	......	......	......	......	......	....	....	....
4×9-4-2-10-A	III-13	....	19.1	34.3	32.3	28.6	9.1	27.5	44.0	26.9	5.9	33.4	25.6	21.6	29.6	....	32.9
4×3-11-A-1-A	I-13-24-1	....	19.8	39.7	31.1	30.2	......	18.7†	39.7	......	......	28.2†	22.5	......	27.5	....	30.2
5×2223	III-17	....	......	......	34.8	......	......	......	......	......	......	......	......	......	....	....	....
Stanley A	....	....	......	......	......	......	......	......	42.6	......	......	......	28.0	......	33.8	....	....
H.B.S.	Check	169	11.6	35.1	30.3	25.7	2.0	17.0	36.9	18.6	2.6	24.7	23.8	17.0	31.0	21.5	30.5
H.B.S.×Well. Fife	I-15-103	999	......	41.1†	28.4	......	......	......	35.7	......	......	......	20.7	......	31.7	....	29.1

* Single plot. † Two-plot test.

In the *vulgare* group, therefore, our report is a comparison of several nursery selections, Marquis and Bluestem, Minnesota No. 169. Average yields are given in Table VI for the crop seasons of 1916, 1917, and 1918. In the comparison as here made, commercial Marquis III-13, Minnesota accession 1240, is used as the standard Marquis sort. Yields of this variety as compared with Minnesota No. 169 give further evidence to show that Bluestem No. 169 is inferior to Marquis in yielding ability. The only test in which Bluestem performed as well as Marquis was made at University Farm in 1918. This was a very favorable year at University Farm for both early and late varieties of wheat. Even under this test Marquis appears equally as good as Bluestem. There seems, therefore, little use in growing Bluestem wheat.

Two sorts belonging to the Preston group have been tested in all seasons and at all stations. II-06-39 is an incross made in 1906 and this is the sole survivor of several other similar selections which were tested for many years in centgener plots. I-15-151 is a selection of Velvet Chaff. Both of these sorts appear about equal to Marquis on a basis of yield. Therefore they should be tested in field varietal plots.

Several Marquis selections have been made but the test has not been continued long enough to determine their value. Four sorts, I-16-77, I-16-64, I-16-81, and I-16-86 will be further tested at University Farm and several substations.

None of the crosses between winter and spring wheat have given evidence of being more valuable than Marquis. Many of these are much better than Bluestem, Minnesota No. 169. Nursery series No. II-08-17 appears to deserve further test at University Farm in field plots. This new sort resembles its Turkey parent in habit of plant and produces corneous red seeds.

Variety 4 × 9-4-2-10-A is the result of a Durum-Common cross made many years ago in the rust-breeding nursery.[7] As it seemed promising as a partially resistant sort, it was placed in the agronomy nursery. It has given about the same yield as Marquis, its performance being especially favorable at the Crookston substation. It is a bearded wheat with smooth, brownish chaff. It should be further tested in field plots at the Crookston station.

METHODS OF ELIMINATION OF LOW YIELDERS

For the row tests, three systematically distributed plots of three rows each have been used for each sort except where sufficient seed has not been available, yield being taken on the central row of each plot. Check plots of Haynes Bluestem similarly handled have been used in determining the degree of soil heterogenity. By finding the probable error of a single determination of three systematically distributed check plots, a fair idea of the accuracy of the test can be obtained. The method used for determining higher yielding sorts for the season in question is, higher yielding sort minus (0.6745 × S.D. of the averages of three systematically distributed check plots × 3). The resultant figure is a yield below which all sorts may be discarded, the chances being 21 to 1 of not discarding a high yielding sort for the season in question.

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[7] Coöperative work under the direction of E. M. Freeman of the Division of Plant Pathology and Botany, and J. H. Parker of the Office of Cereal Investigations, U. S. Dept. of Agr.

The following standard deviations have been obtained on the basis of the Haynes Bluestem check rows. Probable errors and elimination figure are also listed.

Location	Years	S. D.	P.E. × 3	Higher yielding sort minus P.E. × 3
University Farm	1916	1.5	3.0	23.1 — 3.0 = 20.1
University Farm	1917	1.5	3.0	45.0 — 3.0 = 42.0
University Farm	1918	1.5	3.0	36.5 — 3.0 = 33.5
Crookston	1918	2.3	4.6	57.7 — 4.6 = 53.1
Morris	1918	1.0	2.0	46.7 — 2.0 = 44.7
Waseca	1918	1.9	3.8	39.9 — 3.8 = 36.1
All locations	All years	....	3.2	32.5 — 3.2 = 29.3
Season of 1918	....	....	3.4	39.4 — 3.4 = 36.0

In obtaining the elimination figure for all years, the averages of the probable errors for University Farm in 1916, 1917, and 1918, and the tests at Crookston, Morris, and Waseca in 1918 have been used. For 1918 the average of the probable errors for 1918 only has been used.

COMPARISON OF PURE LINE DURUM SORTS

Data obtained in 1917 and 1918 at University Farm and in 1918 at Waseca, Morris, and Crookston are available for the comparison of certain durum sorts. Acme is a South Dakota pure line, while D-1 and D-5 are North Dakota selections. Mindum is a Minnesota selection which has been identified as belonging to the Arnautka group by J. A. Clark of the Office of Cereal Investigations. Speltz Marz also probably belongs to the Arnautka group. These two selections in themselves are a fine demonstration of the necessity of introducing pure lines. Both belong to the Arnautka group and in 1918 both gave higher yields than Acme, D-1, or D-5, altho Speltz Marz proved no better than Kubanka 2094.

Mindum, however, proved a significantly higher yielder than any other durum or *vulgare* sort which was tested at all stations. As there was no rust of any importance in 1918, it would seem that the yield of Mindum was due to some high yielding ability rather than to rust resistance. Its performance for all years that it was tested was very good and it has been the highest yielding sort as determined by a replicated rod-row test in each of the following years and localities: University Farm 1916, 1917; Crookston 1916, 1918; Morris, 1916. These results show that in a rust epidemic season such as 1916, it may be expected to outyield common wheat.

HISTORY OF MINDUM WHEAT

A durum wheat was originally introduced at University Farm in 1896 under the name of Hedge Row. No record of its source was given in the Minnesota accession number book, but the statement has been made that it was a head selection from a field of common wheat. From 1896 until the present time it has been grown in the nursery.

It was increased in 1905 and given a new Minnesota number, 951, and was sent some years later to the Crookston station. Its performance at that station in 1916, which was a bad year for rust, is of some interest.

Variety	1916 yield Bushels
Mindum (Hedge Row)	16.6
Kubanka, C. I. 1440	11.0
Kubanka, C. I. 4063	12.7
Kubanka, Minn. accession No. 990	6.2
Marquis	5.8

It also proved to be the highest yielder of a considerable number of sorts tested at the Northwest substation at Crookston, for the period 1913 to 1916, inclusive. The following are the average yields for this six-year period for several varieties (Selvig, 1916).

Variety	Average yield Bushels
Mindum (Hedge Row)	25.7
Kubanka, Minn. accession No. 990	24.4
Marquis	22.3
Preston	22.3
Minnesota No. 169	19.2

As it has proved its yielding ability in the row test as here reported and also in the plot tests as carried out in the season of 1916, it seems that it deserves to be distributed as a pedigreed durum for Minnesota. It was named Mindum in 1918 for the purpose of distinguishing it from commercial Arnautka. The name Hedge Row was changed because it did not conform to the plan adopted by the American Society of Agronomy, that single words should be used in naming varieties.

The writers desire to call the attention of agronomists to the well-known fact that a commercial variety is often composed of many types which differ only in such agronomic characters as yield and strength of stalk. While realizing the value of variety classification, we must not lose sight of the fact that some pure lines of the same variety are much more desirable from an agronomic standpoint than others.

OATS

The oat-breeding work conducted at the Minnesota station has been chiefly testing commercial varieties in comparison with pure line selections made from them. These systematic selections have shown what can be accomplished by this means and have indicated the parental material which will be used as a basis of attempt to produce higher yielding, non-lodging sorts by crossing.

The data presented in Table VII are based (except where otherwise noted) on three systematically distributed plots for each of three years 1916, 1917, and 1918. Yield is given for each year as well as the averages for two and three years respectively. The averages only are given for the other characters.

SOME PURE LINES SUPERIOR TO OTHERS

Taking up first a comparison of yields, a fact well known to plant breeders becomes apparent, namely, several selections of the same variety may give a wide range as to yield. For instance, the two-year averages of selections I-08-2 and I-16-26, both of which belong to the Swedish Select group, show a difference of 8 bushels. Within the Lincoln group, which to the writers seems closely related phenotypically to the Swedish Select group, the three-year averages show an extreme difference of 6 bushels. The Sixty Day selections first grown in rod rows in 1918 illustrate somewhat more strikingly the difference between selections. Nursery number I-17-76 yielded 17.3 bushels less than I-17-72. It must be remembered, too, that the selections grown in the rod rows represent only the most promising ones as revealed by the head rows.

PURE LINES COMPARED WITH COMMERCIAL VARIETIES

Considering next the yields of the commercial sorts in comparison with the respective selections made from them, it will be observed that in general the selections outyield the commercial varieties from which they were made. This, of course, is to be expected where the lower yielders have been eliminated as they appeared. A commercial Swedish Select, III-12, Minnesota Accession No. 462, yielded as an average of two years 8.3 bushels less than a selection, I-12-6, made from it. Likewise, selection I-11-7 yielded 6 bushels more than commercial III-11, Minnesota Accession No. 439. The two-year averages of the pedigreed strains of Black Tartarian show two out of three yielded more than the commercial sort. In 1918, but four of ten pedigreed strains gave a better yield than the commercial Sixty Day from which the strains were isolated.

TABLE VII

Yields of Oats and Agronomic Characters, Rod Row Test, 1916-1918

Name	N. S. N.	Yield per acre			Average yield 1917-18	Average yield 1916-18	Average weight 1917-18	Date heading 1918	Average height 1917-18	Average lodging 1917-18	Average lodging 1917-18
		1916	1917	1918							
		Bushels	Bushels	Bushels	Bushels	Bushels	Lbs. per bu.		Inches	Per cent	Degrees
Minota	I-06-11	67.9	90.8	88.6	89.7	82.4	34.5	6/24	39	30	26
Minota	I-06-24	64.8	91.6	89.1	90.4	81.8	34.8	6/24	39	12	20
Swedish Select	I-08-2	58.0	88.9	70.4	79.7	72.4	36.0	6/23	41	63	36
Swedish Select	I-15-99	62.1†	82.0	87.5	84.8	77.2	35.8	6/23	45	57	61
Swedish Select	I-15-47	64.2†	85.8	80.9	83.4	77.0	34.8	6/23	45	64	48
Swedish Select (462)	III-12	58.1	79.2†	81.9	80.6	73.1	34.0	6/23	43	75	62
Swedish Select	I-12-6	....	87.6†	90.1	88.9	....	34.8	6/22	41	73	54
Swedish Select (439)	III-11	58.8	78.4	75.1	76.8	70.8	34.5	6/24	43	69	72
Swedish Select	I-11-7	....	84.5†	81.1	82.8	....	35.0	6/23	43	68	71
Swedish Select (466)	III-11	60.7	80.1	87.0	88.6	75.9	35.3	6/24	44	74	73
Swedish Select	I-11-18	....	78.2†	85.3	81.8	....	34.8	6/22	42	68	73
Swedish Select	I-16-4	....	92.2*	77.1	84.7	....	33.8	6/24	43	78	40
Swedish Select	I-16-26	....	93.8*	81.5	87.7	....	34.8	6/23	42	44	34
Lincoln	I-15-164	59.8†	81.4	97.7	89.6	79.6	36.3	6/26	43	20	33
Lincoln	I-15-125	58.4†	88.3	94.5	91.4	80.4	36.0	6/25	44	42	32
Lincoln	I-15-3	51.7†	96.1	75.4	85.8	74.4	34.8	6/25	44	53	39
Lincoln	I-17-8	....	....	77.6	77.6‡	....	33.0‡	6/27	40‡	75‡	38‡
Lincoln	I-17-27	....	....	77.7	77.7‡	....	35.0‡	6/27	36‡	67‡	7‡
Swedish Victory (525)	III-16	48.5*	104.1*	80.7	92.4	....	36.5	6/25	44	46	24
Victory (514)	III-17	....	100.9†	83.9	92.4	....	36.8	6/26	44	57	36
Silvermine	I-14-16	73.5	93.6	73.5	83.6	80.2	35.5	6/25	44	58	43
Silvermine	I-14-17	66.8	93.3	77.1	85.2	79.1	35.0	6/25	43	64	40
Silvermine	I-14-19	73.2	87.7	81.5	84.6	80.8	36.0	6/24	43	61	47
Silvermine	I-14-30	63.7	89.7	74.9	82.3	76.1	35.5	6/24	42	36	45
Silvermine (382)	III-12	66.0*	89.1	76.8	83.0	77.3	34.5	6/23	42	53	71
Silvermine	I-12-16	....	94.1†	76.5	85.3	....	34.5	6/25	43	71	57
Scottish Chief	I-15-83	69.4†	88.7	87.8	88.3	82.0	34.0	6/25	44	45	49
Sixty Day (261)	III-16	....	70.4†	75.7	73.1	....	30.8	6/17	36	74	64
Sixty Day	I-17-52	....	....	72.6	72.6‡	....	28.0‡	6/18	36‡	100‡	53‡
Sixty Day	I-17-54	....	....	71.5	71.5‡	....	28.0‡	6/18	34‡	97‡	52‡
Sixty Day	I-17-57	....	....	78.8	78.8‡	....	30.5‡	6/17	34‡	97‡	60‡
Sixty Day	I-17-60	....	....	76.0	76.0‡	....	26.0‡	6/15	35‡	100‡	55‡
Sixty Day	I-17-70	....	....	74.9	74.9‡	....	28.0‡	6/16	34‡	100‡	57‡
Sixty Day	I-17-72	....	....	81.3	81.3‡	....	32.0‡	6/17	34‡	43‡	30‡
Sixty Day	I-17-74	....	....	74.2	74.2‡	....	28.0‡	6/16	34‡	100‡	60‡

TABLE VII—*Continued*

Yields of Oats and Agronomic Characters, Rod Row Test, 1916-1918

Name	N. S. N.	Yield per acre 1916	Yield per acre 1917	Yield per acre 1918	Average yield 1917-18	Average yield 1916-18	Average weight 1917-18	Date heading 1918	Average height 1917-18	Average lodging 1917-18	Average lodging 1917-18
		Bushels	Bushels	Bushels	Bushels	Bushels	Lbs. per bu.		Inches	Per cent	Degrees
Sixty Day	I-17-75	....	....	70.7	70.7‡	....	28.0‡	6/15	35‡	100‡	55‡
Sixty Day	I-17-76	....	....	64.0	64.0‡	....	26.0‡	6/17	34‡	68‡	35‡
Sixty Day	I-17-79	....	....	80.6	80.6‡	....	27.0‡	6/17	34‡	47‡	57‡
Iowa 103	III-18	....	....	73.3	73.3‡	....	27.5‡	6/17	35‡	70‡	23‡
Iowa 105	III-18	....	....	77.4	77.4‡	....	30.0‡	6/17	34‡	100‡	13‡
Cornell 91-B	III-14	56.7	95.9†	78.8	87.4	77.1	33.0	6/23	36	18	28
Cornell 103-B	III-14	48.6	96.1†	83.4	89.8	76.0	32.8	6/28	44	52	48
Kherson	I-15-17	68.8†	84.1	81.6	82.9	78.2	30.5	6/18	34	57	60
Dept. 5168	I-06-28	58.2	78.8	68.9	73.9	68.6	31.8	6/17	35	43	19
S. P. I. 33644	I-17-40	....	....	71.1	71.1‡	....	29.5‡	6/17	34‡	48‡	60‡
S. P. I. 33644	I-17-34	....	....	75.7	75.7‡	....	30.0‡	6/17	32‡	10‡	33‡
Irish Victor	I-17-90	....	....	75.0	75.0‡	....	32.5‡	6/27	37‡	13‡	18‡
Irish Victor	I-17-93	....	....	74.0	74.0‡	....	30.0‡	6/23	37‡	100‡	67‡
Irish Victor	I-17-94	....	....	82.2	82.2‡	....	32.0‡	6/17	35‡	70‡	23‡
Irish Victor (?)	I-15-16	55.6†	97.8	86.3	92.1	79.9	35.8	6/25	40	50	21
June (?)	I-14-55	59.2	75.0	82.1	78.6	72.1	31.8	6/23	39	0	0
Archangel/Ely Gothland	II-17-10	....	....	85.5	85.5‡	....	33.5‡	6/24	36‡	33‡	7‡
Wh. Wond./Siberian Ely	II-17-15	....	....	74.6	74.6‡	....	34.0‡	6/25	39‡	53‡	87‡
Garton 473	I-15-33	62.4†	93.1	90.9	92.0	82.1	34.5	6/24	40	50	8
Black Tartarian	I-11-1	....	82.2†	84.3	83.3	....	36.3	6/27	44	50	4
Black Tartarian	I-11-2	....	86.9†	82.2	84.6	....	34.8	6/28	43	50	4
Black Tartarian (438)	III-11	47.6	85.5†	76.8	81.2	70.0	32.8	6/28	41	47	18
Black Tartarian	I-15-40	53.9†	82.4	74.0	78.2	70.1	32.3	6/28	42	21	18
White Tartarian	I-17-4	....	....	70.2	70.2‡	....	34.5‡	6/28	40‡	100‡	13‡
Sparrowbill	I-14-69	40.3	85.5	71.4	78.5	65.7	38.3	6/27	43	50	17
Garton 784	I-15-38	67.8*	90.4	85.3	87.9	81.2	32.5	6/20	39	6	8
Check	....	58.7	92.0	84.7	88.4	78.5	35.5	6/26	43	40	29

* One plot. † Average of two plots. ‡ One year.

METHODS OF DETERMINING THE HIGHER YIELDING SORTS

To aid in discarding low-yielding strains, a somewhat arbitrary figure is adopted. This figure, as has been pointed out, is obtained by taking 3 times the probable error of the averages of three systematically distributed checks and subtracting the product from the highest yielder. All varieties below the difference obtained are considered low yielders for the particular year under observation.

It is of interest to note that the highest yielding Sixty Day selection, I-17-72, also possesses the stiffest straw. Within this group there are two other strains, I-17-76 and I-17-79, which also stand up better than commercial Sixty Day. These three selections were non-lodging sorts in 1917 as tested in head rows.

The first three columns of Table VIII list in descending order the remaining sorts after the elimination figure has been applied. It will be noted that I-06-11 is the only selection which appears all three years. The difference between the yields of I-06-11 and I-06-24 is small in 1916 but the latter is below the elimination figure. Strains I-14-16 and I-14-17 appear in 1916 and 1917, strain I-15-83 in 1916 and 1918, and strains I-15-33 and I-06-24 in 1917 and 1918. Of these six superior yielding lines, the two Minotas are the most non-lodging forms. I-15-33, which is a Garton 473, ranks third in this respect.

The third column of Table VIII shows that none of the early maturing oats yielded enough in 1918 to be classed with the better strains.

TABLE VIII

SORTS REMAINING AFTER ELIMINATION FIGURE HAS BEEN APPLIED; ALSO RESPECTIVE PROBABLE ERRORS ACCEPTED AS MARKING THE LIMITS OF CHANCE FLUCTUATIONS

1916	1917	1918	Average 1917, 1918	Average 1916, 1917, 1918
I-14-16	III-16(525)	I-15-164	III-16(525)	I-06-11
I-14-19	III-17(514)	I-15-125	III-17(514)	I-15-33
I-15-83	I-15-16	I-15-33	I-15-16	I-15-83
I-15-17	III-14(103)	I-12-6	I-15-33	I-06-24
I-06-11	I-15-3	I-06-24	I-15-125	I-15-38
I-15-38	III-14(91B)	I-06-11	I-06-24	I-14-19
I-14-17	I-12-16	I-15-83	III-14(103B)	I-15-125
....	I-16-26	I-15-99	I-06-11	I-14-16
....	I-14-16	....	I-15-164	I-15-16
....	I-14-17	....	I-12-6	I-15-164
....	I-15-33	....	Checks(281)	I-14-17
....	I-16-4	....	I-15-83	Checks(281)
....	I-06-24	....	I-15-38	I-15-17
....	I-06-11	....	I-16-26	III-12(382)
....	....	....	III-14(91B)	I-15-99
....	....	....	I-15-3	III-14(91B)
....	....	....	I-12-16	I-15-47
....	....	....	I-14-17	....
....	....	....	I-15-99	....
....	....	....	I-16-4	....
....	....	....	I-14-19	....
....	....	....	I-11-2	....
Bushels* 6.3	Bushels 12.8	Bushels 9.9	Bushels 8.0	Bushels 5.5

* P. E. accepted as marking limits of chance fluctuation.

This season was particularly favorable for the development of medium and late maturing varieties, which may account largely for the results obtained.

The last two columns of the same table list in descending order the pedigreed and commercial sorts which remain after an elimination figure has been applied to the average yields of two and three years respectively. In the former case the elimination figure is obtained by taking the average of the probable errors (3 × P.E. of average of 3 systematically distributed checks) for 1917 and 1918 divided by the $\sqrt{2}$. In the latter, the average probable error of the three years divided by the $\sqrt{3}$ is used. The resultant quotient in each case is subtracted from the highest two-year and three-year average yields, respectively. The above method eliminates approximately one half of the sorts grown and is consequently, for the crop and seasons under discussion, a less severe criterion to use than considering each year alone.

Heading the fourth column of Table VIII are two sorts which on the basis of a two-year average give considerable promise of being high yielders. They also seem to have somewhat stiff straw. Both of these sorts, which belong to the Lincoln group, were obtained under the variety name Victory. III-16 (525) was obtained from Svalöf, Sweden, and III-17 (514) from Saskatoon, Canada. The other more promising selections that appear in the two-year average column likewise appear in the three-year average column, so a study of the latter will suffice.

TABLE IX

BETTER STRAINS GROUPED ACCORDING TO VARIETIES

Variety	N. S. N.	Three-year average yield	Three-year average lodging	Three-year average lodging
		Bushels	Per cent	Degrees
Minota	I-06-11	82.4	53	51
Minota	I-06-24	81.8	41	47
Garton 473	I-15-33	82.1	67	35
Scottish Chief	I-15-83	82.0	63	64
Garton 784	I-15-38	81.2	37	37
Silvermine	I-14-19	80.8	74	65
Silvermine	I-14-16	80.2	72	62
Silvermine	I-14-17	79.1	76	60
Silvermine	III-12(382)	77.3	68	80
Lincoln	I-15-125	80.4	59	52
Lincoln	I-15-164	79.6	47	78
Irish Victor*	I-15-16	79.9	67	47
Swedish Select	(Checks)	78.5	60	52
Swedish Select	I-15-99	77.2	71	74
Swedish Select	I-15-47	77.0	76	65
Kherson	I-15-17	78.2	71	73
Cornell 91-B	III-14	77.1	45	52

* Possibly Silvermine.

All strains which were not discarded on the basis of a three-year average yield are grouped according to the variety to which they belong in Table IX. In variety groups represented by more than one strain, the best one only is carried on into the variety test plots conducted by the farm crops section. The two Minota selections hardly differ sufficiently to warrant the choice of one over the other. I-06-11 yields slightly more than I-06-24 but the latter possesses slightly stiffer straw. Within the Silvermine group there is likewise little difference between the three pedigreed sorts, but line I-14-16 was chosen. Of the two Lincolns, I-15-125 was selected. Within the Swedish Select group the checks have stiffer straw than either of the two selections. The former also yield slightly more. The other variety groups appearing in the table deserve to be carried into the subsequent variety tests by their respective lone representatives.

The yields of five of the better sorts obtained in 1918 at three of the substations and at University Farm are presented in Table X.

TABLE X

YIELDS OF FIVE BETTER SORTS AT FOUR LOCATIONS

Variety	N. S. N.	Yield per acre				
		U. Farm	Morris	Crookston	Waseca	Average
		Bushels	Bushels	Bushels	Bushels	Bushels
Victory (514)	III-17	83.9	73.8	101.3	88.7	86.9
Minota	I-06-11	88.6	69.4	96.1	87.2	85.3
Irish Victor*	I-15-16	86.3	62.2	111.1	73.7	83.3
Silvermine	I-14-16	73.5	70.3	92.3	92.4	82.1
Garton 784	I-15-38	85.3	70.2	83.9	87.1	81.6

* Possibly Silvermine.

These figures strikingly show the necessity of testing strains in the vicinity for which they are intended. A different sort gave the best yield for each different location. Results also show the fluctuation in yields to be expected and hence the need of trying out a strain over a period of several years in order to obtain trustworthy data. Within two or three years' time the plant breeder can hope for nothing more than to isolate the better strains; several additional years are required to determine the best strains for each particular locality.

COMPARISON OF METHODS FOR DETERMINING THE PROBABLE ERROR OF REPLICATED PLOTS

In some cases sufficient check plots can not be grown to obtain a reliable probable error for yield. The pairing method of Wood and Stratton (1910) may be used in this case to determine probable error. For the purpose of contrasting these methods, the probable error as determined for the check plots is here compared with the pairing method for the nursery rod-row 1918 oat test. In the pairing method, check plots were not used for the computations. This comparison is of interest, as the pairing method, in which the deviations were squared, was used for the 1918 barley test.

Briefly the procedure was as follows: Each plot in the first series was averaged with its respective duplicate in the second series and similarly each plot in the second series was averaged with its respective duplicate in the third series. The deviation of each pair from their average was expressed in percent. In this way 121 percentages were obtained, the mean of which was 6.94. This percentage mean represents the average deviation by the pairing method of all plots except the checks. To express the percentage in bushels, a mean yield must be obtained. In this case the average of all the plots except the checks was taken as the mean yield. By taking the average deviation percentage (6.94) of the mean yield (79.3 bushels) in 1918, the average deviation in bushels (5.5) for a single plot is secured. Dividing this figure by $\sqrt{3}$, as yields are based on the average of three plots, and multiplying the quotient by 3 a product of 9.5 bushels is obtained, the chance being 21 to 1 that it marks the limits of chance fluctuation. When the above product is subtracted from the highest yield, an elimination figure results which is used in the same way as that derived from the checks.

It will be noted that the above probable error (9.5 bushels) marking the limits of chance fluctuation differs only 0.4 bushels from a similar figure (9.9 bushels, Table VIII) secured by means of the check plots. The expression of a probable error may be secured by still another method which is identical with the one just outlined except that the average percentage deviations are first squared and then the square root extracted from their mean. By applying this method to the above crop, 11.6 bushels is obtained as the figure which marks the limits of chance fluctuation. It is evident that this last method gives the highest probable error.

GENERAL SUMMARY

METHODS OF TECHNIC

1. The breeding of small grains falls naturally under three heads. These are: (1) introductions; (2) selections; (3) crosses followed by selection.

2. New introductions are essential if the breeder is to have the best material as a basis for his studies. The production of a new variety adapted to a certain locality is a waste of time if the same end result can be obtained through introductions.

3. New introductions that appear promising in preliminary row tests are used as a basis of selection. Selections from commercial sorts

as grown by farmers are also made, as nearly all commercial sorts are mixtures of strains.

4. The head selection method is used, from 50 to 200 heads being selected the first year. Non-promising sorts are eliminated in the field. The second year three systematically distributed plots of a single 18-foot row each are grown for each selection, one foot being removed from each end before harvest. Those that are not eliminated are tested the third year in three plots of three 18-foot rows each, the central row only of each plot being used for the yield test. Border rows are grown to obtain more accurate data on lodging and to overcome competition between nearby sorts.

5. Crosses are made between parental sorts selected because of some particular characters.

(a) No selections are made in the F_1 of a cross, as all plants are of the same genotype. Non-crosses are immediately discarded.

(b) A large plot is grown in F_2, and individual plants selected.

(c) Seed of each plant selected in F_2 is planted in a separate plot in F_3 and characters of resulting plants observed. Some plots are homozygous for all characters, some are heterozygous for some characters and homozygous for others, while some show segregation as in F_2.

(d) Selection by the individual plant method is continued until many homozygous forms are obtained.

(e) As homozygous sorts appear they are placed in the rod-row test and handled thereafter the same as selections.

(f) All row tests are examined yearly for possible genetic impurities. Reselection is practiced if the type is segregating. Mechanical mixtures, if any, are rogued out.

6. A bulk plot of a cross is grown for several years. It becomes homozygous automatically according to the formula $\left(\frac{2^n-1}{2^n}\right)^m$ in which n is the number of generations elapsing since the cross, and m is the number of allelomorphic pairs by which the parent sorts differ. After several years individual selection is practiced.

7. Rod-row plots of a standard sort are grown every third to fifth plot and yields determined. The probable error of the average of 3 plots systematically distributed as determined by the checks is multiplied by three, and when subtracted from the higher yielding sort a somewhat arbitrary figure is obtained below which it is considered safe to discard all sorts for the season in question without eliminating a high yielding strain. A similar method is used in determining higher yielding sorts after a three-year test.

8. Promising sorts are also tested in rod rows in coöperation with several of the substations.

9. After a three-year test in rod rows, sorts of promise are placed in the plot varietal test conducted by the section of farm crops.

10. Pedigreed sorts produced at this or other stations are ultimately distributed to the farmers. The investigational staff of the division acts as a board to determine, *on the basis of performance,* which sorts to distribute.

WINTER WHEAT

1. New introductions obtained from C. E. Leighty and J. A. Clark, of the Office of Cereal Investigations, proved less hardy than selections and crosses which were made at this station many years ago.

2. Some selections and crosses stand up much better than others. Among these both subcorneous and substarchy types were found.

3. Odessa, a late-maturing sort, was crossed with Turkey, which matures somewhat earlier. Homozygous forms have been produced which range in maturity from the early to the late parents.

4. Several of the crosses between Odessa and Turkey proved as hardy as the Odessa parent, or slightly hardier, and gave much higher yields.

5. Some of the Odessa-Turkey crosses, of which 325 selections were carried in centgener plots, were non-hardy. Other crosses were made, none of which gave as hardy wheat as when Odessa was used as a parent. This shows the value of using as a parent a type which excels for the character desired.

6. Several pure lines excelled in hardiness. Those that deserve mention are a Turkey selection, I-03-120; Big Frame I-06-6; and I-03-229, a bearded, smooth, red-chaffed form with subcorneous kernels which was selected from an introduction from Padui, Russia.

SPRING WHEAT

1. Coöperative rust investigations with the hope of producing a rust resistant bread wheat of milling quality limited other agronomic breeding studies with spring wheat. Recent pathological investigations (Stakman, et al, 1919) in which many biologic forms have been found make questionable the value of further rust-breeding studies. The breeder must probably await the result of more knowledge in this field before attacking the problem with any great expectation of a favorable solution.

2. Row tests of bread wheat sorts show that Marquis is a very desirable variety for Minnesota conditions.

3. Several crosses made in 1908 between Turkey Winter and Wellman's Fife are better than Haynes Bluestem, Minnesota 169. None, however, seem of more value than Marquis.

4. Mindum, a selection belonging to the Arnautka group, has given evidence of being a valuable sort for Minnesota. This conclusion is

reached on the basis of a comparison with D-1 and D-4, North Dakota selections; Acme, a South Dakota pedigreed sort; and other Arnautka and Kubanka pedigreed varieties. It will be distributed as a Durum wheat adapted to Minnesota conditions.

OATS

1. Oats breeding as reported consists of a study of the value of selection.

2. Some pure lines of a commercial variety are much better, as determined by yield and lodging notes, than others.

3. These studies show that it is a comparatively easy task to produce a higher yielding sort by selection from a commercial variety.

4. Results for the Sixty Day variety are especially striking altho only a single year's test in rod rows is available. One pure line, I-17-72, stood up better than commercial Sixty Day and also excelled in yield. It seems of much promise as compared with Iowa 103 which was produced at the Ames station and which has stiffer straw than commercial Sixty Day.

5. On the basis of the three-year yield test, pure lines of several varieties gave evidence of promise. From the breeder's standpoint it would seem that the isolation of a higher yielding strain is more important than variety. Selections of the following varieties deserve further test: Minota (a Minnesota selection), Garton 473, Garton 784, Scottish Chief, Irish Victor, Silvermine, Lincoln, and Kherson.

6. All that the breeder can hope to accomplish in three or four years is to determine the sorts which deserve further test. The final trial is for the purpose of determining the adaptability of the sorts to special conditions and localities.

7. The pairing method for determination of probable error gave about the same result for the 1918 oat test as by the use of check plots systematically distributed and grown every third to fifth plot.

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PART II. INVESTIGATIONS IN BARLEY BREEDING[1]

By H. V. HARLAN and H. K. HAYES

INTRODUCTION

During the 5-year period from 1913 to 1917 inclusive, Minnesota produced slightly more than 17 per cent of the total barley crop of the United States.[2] Minnesota ranks second among the states, California leading by a small margin. A small increase in average yield per acre would, therefore, be of considerable value to Minnesota agriculture.

Prior to 1915 there were two barley breeding nurseries at University Farm, one under the direction of a man from the Office of Cereal Investigations of the Bureau of Plant Industry and the other under the direction of the Minnesota Experiment Station. In 1915 the two barley nurseries were combined. This report is a statement of the performance in replicated rod-row tests of the better sorts from both nurseries. It is of general interest, as the varieties here represented comprise pure line selections and crosses from widely varying types, systematic introductions having been obtained from important barley producing countries of the world.

As this barley work is coöperative, no Minnesota accession number is given to these different sorts. The nursery series numbers are similar to those previously discussed, i.e., Class I refers to selections, Class II to crosses, and Class III to new introductions which have not been pedigreed. The final number in the series for crosses and selections refers to the serial number of the head selected. In the wheat and oat work the second number of the series refers to the year in which the selection or cross was first made. In the barley studies this number refers to the year in which the sort was placed in the row test with the exception of a few sorts which came from the original Minnesota nursery and which received a nursery series number in 1915 or prior to that time.

The average results for 68 selections and crosses are given in Table I. The following notes are presented in columns from left to right: Name; nursery series number; botanical type; i.e., 6-rowed or 2-rowed, coast, lax or dense head, and smooth or rough awn; average date of awn emergence, 1917-1918; average height in centimeters; average per cent lodged, i.e., the proportion of the plot which deviates from the normal or upright condition; average degree lodged, or the average angle which the lodged plant makes with the upright condition; yield per acre 1916, 1917, and 1918; average yield 1916 to 1918, inclusive; and average yield 1917 and 1918. Check plots of Minnesota accession 105, Manchuria, were grown in 1915 and 1916. In 1917 Minnesota No. 184, a high yielding pure-line selection of accession 105, and Chevalier, Minnesota 230, a 2-rowed barley, were added to the test to be used as a basis of determining the performance of the new sorts.

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[1] Coöperative investigations between the Office of Cereal Investigations, U. S. Dept. of Agr., and the Minnesota Agricultural Experiment Station.

[2] U. S. Dept. of Agr. Yearbooks.

Fig. 11. Manchuria, Minn. 184, Field Plots, 1918

RESULT OF HEAD SELECTION

Featherston, Lake City, and Excelsior barleys are the surviving few of a large number of field selections. In 1909 several farms near Red Wing, Minnesota, were visited. From the farm of Mr. Featherston 62 selections were planted in 1910; from the farm of Mr. Luth, 27; and from that of Mr. Myer, 14. In 1911 a second series of field selections was made near Lake City. Fifteen of these selections were carried in the nursery for some years afterwards. In 1914, 27 selections were grown from field selections made in 1913 near Excelsior, Minnesota. Most of those that were not eliminated were afterwards known only as Manchuria Excelsior. In 1915 several head selections were made from Minnesota No. 105. Those which were placed in the row test were known as Manchuria.

Results for these various Manchuria selections show that some sorts are much better yielders than others. I-16-2, for example, has given a low yield each year that it has been tested, while I-15-2 has proved one of the highest yielders for each of the three years that it has been grown.

The origin of some of the other sorts gives an idea of the many sources from which this material was assembled. Trebi came from Asiatic Turkey; Lion, a smooth-awned black barley from Russia; C.I. 894 from Venezuela; Odessa from Canada; while several plant selections have been made from other introductions of the Department of Agriculture. We have here an opportunity of comparing many different varieties from all over the world.

It is of considerable interest to note that nearly as wide variations in yielding ability are found within a variety, such as Manchuria, as are obtained by comparing different varieties. This shows the value of pure-line breeding and ultimate introduction of the higher yielding sort.

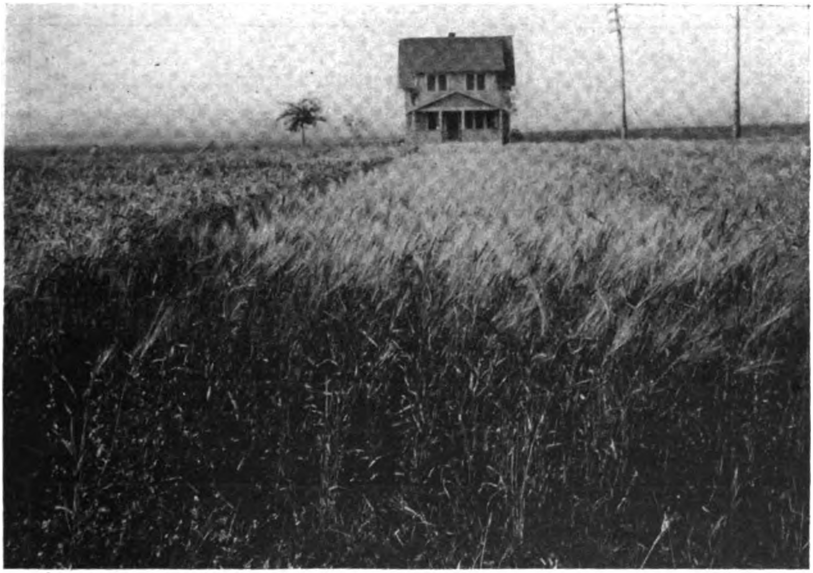

Fig. 12. Lion × Manchuria, II-16-91, Variety Test, 1918
This is a smooth-awned barley which gave the highest yield of any sort in the plot test at University Farm in 1918.

SMOOTH-AWNED BARLEYS

A considerable number of crosses between Lion, a smooth-awned black barley, and Manchuria have been grown. The results prove that smooth-awned barley of high yielding ability is a reality. Lion, the

TABLE I

Averages for Barley Selections and Crosses Grown at University Farm 1916 to 1918 Inclusive, Rod Row Tests Replicated Twice

Name	N. S. N.	Botanical type[1]	Average date of awn emergence	Average height cm.	Average per cent lodged	Average degree lodged	Yield per acre				
							1916	1917	1918	Average	Av. 1917-18
							Bushels	Bushels	Bushels	Bushels	Bushels
Featherston	I-16-32	6 L	6/26	97	66	48	44.7	44.5	56.4	48.5	50.5
Featherston	I-16-2	6 L	6/24	80	96	64	38.0	26.1	52.7	38.9	39.4
Featherston	I-16-8	6 L	6/26	95	85	48	39.8	28.1	52.6	40.2	40.4
Featherston	III-15-129	6 L	6/25	85	74	54	36.1	37.3	51.8	41.7	44.6
Minn. No. 105 Selected	I-16-21	6 L	6/27	94	78	51	55.5	29.5	58.4	47.8	44.0
Minn. No. 217	I-16-29	6 L	6/26	96	80	55	49.8	46.2	51.4	49.1	48.8
Lake City	I-16-33	6 L	6/25	93	59	32	44.5	38.4	49.3	44.1	43.9
Lake City	I-16-60	6 L	6/26	89	56	30	44.4‡	30.5	47.0	40.6	38.8
Manchuria Ex.	I-16-44	6 L	6/27	96	68	55	48.5	40.9	52.5	47.3	46.7
Manchuria Ex.	I-16-64	6 L	6/26	96	30	29	45.6	36.0	52.0	44.5	44.0
Manchuria	I-16-66	6 L	6/26	96	58	29	50.5‡	36.4	61.8	49.6	49.1
Manchuria	I-15-1	6 L	6/28	95	73	55	47.1‡	45.3	56.7	49.7	51.0
Manchuria	I-15-2	6 L	6/28	99	82	69	53.4‡	46.2	66.1	55.2	56.2
Manchuria	Minn. No. 184	6 L	6/21	86*	55*	15*	....	....	54.6	....	....
Manchuria	I-18-4	6 L	6/22	89*	100*	58*	....	....	54.9	....	....
Trebi	I-16-14	6 C	6/27	76	55	52	46.5	47.1	53.6	49.1	50.4
Highland Chief	I-16-31	6 L	6/25	95	96	80	46.3	49.8	69.4	55.2	59.6
C. I. 894	I-16-84	6 L	6/28	94	40	31	44.4‡	42.4	51.7	46.2	47.1
Scotch	I-16-46	6 L	6/26	89	84	66	30.9	43.3	53.4	42.5	48.4
Sandrel	I-16-3	6 L	6/24	77	85	53	42.1	41.6	66.3	50.0	54.0
Servian	I-16-15	6 L	6/27	81	44	26	39.3	32.3	61.2	44.3	46.8
Odessa	I-18-2	6 D	6/22	86*	100*	20*	....	....	58.9	....	....
Algeria	I-18-6	6 L	7/3	98*	100*	37*	....	....	41.1	....	....
Switzerland	I-18-7	6 L	6/25	86*	33*	32*	....	....	59.2	....	....
Lion	I-16-13	6 L S	6/23	75	52	54	49.7	46.1	67.0	54.3	56.6
Lion × Featherston	II-16-88	6 L S	6/29	88	33	30	47.2‡	48.8	43.8	46.6	46.3
Lion × Featherston	II-17-3	6 L S	6/21	81†	99†	84†	....	51.7‡	59.8	....	55.8
Lion × Manchuria	II-16-89	6 L R	6/28	93	37	35	45.8‡	42.3	48.7	45.6	45.5
Lion × Manchuria	II-16-91	6 L S	6/21	77	34	31	42.3‡	51.7	59.1	51.0	55.4
Lion × Manchuria	II-16-92	6 L S	6/20	78	47	29	50.0‡	51.5	42.3	47.9	46.9
Lion × Manchuria	II-16-101	6 L S	6/20	79	34	44	52.5‡	43.3	45.1	47.0	44.2
Lion × Manchuria	II-16-104	6 L S	6/23	80	64	46	40.3‡	43.3	56.5	46.7	49.9
Lion × Manchuria	II-17-1	6 L S	6/20	85†	76†	61†	....	51.9‡	64.5	....	58.2
Lion × Manchuria	II-17-2	6 L I	6/22	84†	98†	85†	....	67.8‡	53.5	....	60.7
Lion × Manchuria	II-17-4	6 L S	6/20	74†	100†	89†	....	60.4‡	57.5	....	59.0
Bay Brewing × Lion	II-17-6	6 L I	6/24	82†	95†	78†	....	51.5‡	58.3	....	54.9
Bay Brewing × Lion	II-17-11	6 L S	6/23	82†	91†	79†	....	42.8	50.0	....	46.4

TABLE I—*Continued*

AVERAGES FOR BARLEY SELECTIONS AND CROSSES GROWN AT UNIVERSITY FARM 1916 TO 1918 INCLUSIVE, ROD ROW TESTS REPLICATED TWICE

Name	N. S. N.	Botanical type[1]	Average date of awn emergence	Average height cm.	Average per cent lodged	Average degree lodged	Yield per acre				
							1916	1917	1918	Average	Av. 1917-18
							Bushels	Bushels	Bushels	Bushels	Bushels
Lion × Bay Brewing	II-17-13	6 L S	6/29	83†	74†	73†	....	46.4‡	57.7	....	52.1
Lion × Bay Brewing	II-17-14	6 L S	6/29	91†	80†	61†	....	45.1‡	54.6	....	49.9
Bay Brewing	I-18-3	6 C	6/24	81*	100*	88*	....	....	59.4	....	....
Lion × Mariout	II-17-7	6 D S	6/21	69†	100†	90†	....	56.3	62.7	....	59.5
Lion × Mariout	II-17-8	6 D S	6/18	67†	99†	85†	....	51.1	59.7	....	55.4
Mariout	I-15-130	6 D	6/23	68	65	61	51.2	29.0	54.2	44.8	41.6
S. African × Manchuria	II-16-47	6 D	6/22	80	35	36	57.7	50.5	61.1	56.4	55.8
S. African × Manchuria	II-16-77	6 L	6/22	79	22	34	51.9‡	52.0	55.5	53.5	53.8
20375 × Svanhals	II-17-17	6 L	6/29	98†	68†	41†	....	40.9‡	50.0	....	45.5
456 × Svanhals	II-16-37	2 D	6/30	96	47	40	43.0	47.9	45.6	45.5	46.8
B. D. Bill	I-16-40	2 L	6/28	100	62	49	45.5	43.2	49.1	45.9	46.2
Selection from G. I. 578	I-16-61	2 D	6/29	99	59	40	51.4‡	42.2	39.7	44.4	41.0
Bohemian × Manchuria	II-16-76	2 L	6/29	94	66	49	47.8‡	40.0	38.5	42.1	39.3
Bohemian × Manchuria	II-16-78	2 L	6/29	95	50	31	42.6‡	41.1	45.9	43.2	43.5
Svanhals 19782	I-13-21	2 D	7/2	96	55	69	31.8	40.3	46.4	39.5	43.4
Svanhals × 2R/6R	II-17-23	2 L	6/27	97†	85†	78†	....	49.9‡	43.5	....	46.7
Smyrna × Svanhals	II-17-19	2 D	6/22	79†	22†	21†	....	43.4‡	55.1	....	49.3
Svanhals × Bolton	II-17-21	2 L	6/30	103†	90†	62†	....	44.6‡	43.7	....	44.2
Moravian × Chevalier	II-17-22	2 L	6/29	98†	60†	47†	....	43.9‡	43.8	....	43.9
Svanhals × 2R/6R	II-16-131	2 L	6/28	99	82	70	33.5	37.7	54.0	41.7	45.9
20375 × Svanhals	II-18-1	2 D	6/26	97*	100*	12*	....	....	56.6	....	....
20375 × Svanhals	II-18-5	2 L	6/25	97*	100*	12*	....	....	55.0	....	....
Sel. Abed Bender	I-18-8	2 L	6/24	85*	100*	57*	....	....	53.7	....	....
Chevalier	Minn. No. 230	2 L	6/23	88*	70*	18*	....	....	35.6	....	....
Russian	III-15-121	2 L	6/29	88	70	55	45.8	42.2§	48.8	45.6	45.5
Lake City	I-16-59	2 L	6/29	82	70	58	43.8	41.6‡	44.2	43.2	42.9
New South Wales	III-15-120	6 C	6/21	81	74	62	43.3§	43.1§	54.9	47.1	49.0
Russia	III-15-123	6 L	6/24	86	78	47	41.5§	46.4§	58.3	48.7	52.4
Russia	III-15-124	6 L	6/26	86	78	49	48.0§	47.8§	51.0	48.9	49.4
New South Wales	III-15-125	6 C	6/25	80	77	63	36.5§	43.9§	58.3	46.2	51.1
Russia	III-15-127	6 D	6/29	76	24	20	45.4§	46.9§	46.0	46.1	46.5
Algeria	III-15-128	6 C	6/26	74	65	54	47.5§	38.8§	67.5	51.3	49.6
Check	Minn. No. 105	6 L	6/31	93¶	48¶	80¶	42.2	38.6	54.6‖	45.1	46.6

[1] L, lax; D, dense; C, coast; S, smooth; R, rough; I, intermediate awn.

* Average for one year (1918). † Average of two years (1917-1918). ‡ Single-plot test. § Two-plot test. ‖ Yield of Minn. No. 184, a pure line selection of Accession No. 105. ¶ Average of two years (1916-1917).

black parental sort, gave a slightly larger average yield than any of the crosses which have been grown for the entire three-year period. Some of those which have been tested for the crop seasons of 1917 and 1918 gave slightly higher yields than Lion. On the basis of a comparison of these crosses and Manchuria No. 105 and No. 184, several seem very promising. Thus, in the very near future, smooth-awned barley may be grown by the Minnesota farmer. This will do away with the most unpleasant part of the handling of the barley crop.

Two crosses between Lion and Mariout were tried in 1917 and 1918. Both gave high yields but they lodged rather badly. They have dense heads similar to Mariout and the smooth awns of Lion. Their performance is a further reason for believing that high yielding smooth-awned barley of any head type can be produced by crossing and subsequent selection.

CROSS BETWEEN SOUTH AFRICAN AND MANCHURIA

Two out of 23 selections have survived from the cross between a variety called South African and Manchuria. This South African was a dense-headed sort which stood up well but which gave a very small yield as tested in the nursery. It was not considered worth testing in rod rows. As the crosses have some desirable features the performance of the parental sorts is of interest. Table II gives comparative results for the South African parental sort and Minnesota No. 184, a pure-line Manchuria selection of much promise.

TABLE II

COMPARISON OF YIELDING ABILITY OF SOUTH AFRICAN AND ONE OF THE BEST SELECTIONS OF MANCHURIA

Variety	Minn. No.	N. S. N.	Year	Yield
				Grams
Manchuria	184	I-01-67	1902	471.7
Manchuria	184	I-01-67	1903	621.0
Manchuria	184	I-01-67	1904	465.3
Average				519.3
South African	99	I-97-3	1902	306.0
South African	99	I-97-3	1903	241.9
South African	99	I-97-3	1904	304.5
Average				284.1

These figures give evidence that South African is a poor yielding variety.

One of the two crosses between South African and Manchuria, II-16-47, is a dense-headed variety while II-16-77 is a lax sort. Both sorts are shorter than the average of Manchuria selections, altho either are tall enough for all practical purposes. Not only do these selections excel in yield but they also stand up much better than Manchuria accession No. 105 or No. 184. II-16-47 is of especial value as a non-lodging sort, as it did not lodge to any appreciable degree during any of the three years in which it has been grown.

DETERMINATION OF BETTER SORTS

The ultimate aim of breeding work is to produce a pedigreed sort of higher yielding ability than the ordinary types grown by the farmers of a particular section. These 68 selections, crosses, and new introductions may then be profitably compared on the basis of their yearly production in bushels of grain per acre.

One of the greatest difficulties in field plot experiments is soil variability. Preliminary studies as carried out in Minnesota led to the adoption of three or four systematically distributed plots for each type under test. This does not, of course, control all errors but it is a very important step in tending to overcome possible discrepancies arising from soil heterogeneity. The question then arises as to what difference in yield may be considered significant.

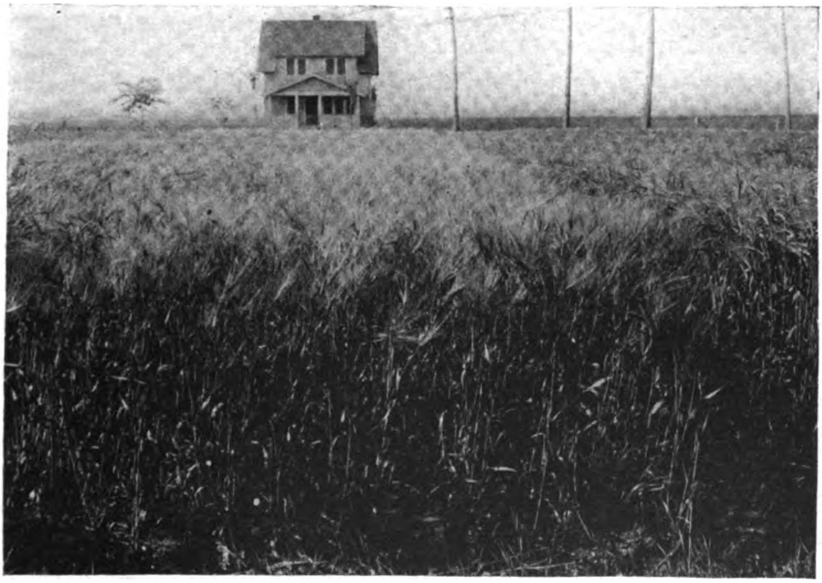

Fig. 13. South African × Manchuria, II-16-47, Variety Test, 1918
A high yielding sort with stiff straw.

The method which has been adopted for our work is based upon the probable error. Thus in 1916 and 1917 the standard deviation of the average yields for three systematically distributed plots was determined for Minnesota No. 105 as grown in check plots. By multiplying this standard deviation by ±0.6745 the probable error for the average yield of three systematically distributed check plots was obtained.

This probable error was then multiplied by 3 and subtracted from the highest yielding variety in the test. This gave a figure below which all types could be eliminated for the season in question, the chances being 21 to 1 that all sorts so eliminated were of lower yielding ability for the particular season than the highest yielding sort.

In 1918 no check plots were grown, the probable error being determined by the pairing method as used by Wood and Stratton.[8] This probable error was multiplied by three and used in the same manner as previously outlined. A comparison for the oat studies shows that this method gives about the same figure as the use of check plots.

In 1917 the highest yielding 6-rowed sort was a smooth-awned barley, II-17-7, with a yield of 56.3 bushels. The probable error for the check variety for three systematically distributed plots was 2.43 bushels. Multiplying this figure by 3 gave 7.3 bushels and, when subtracted from 56.3 bushels, gave 49. Using this as a discard figure, all types which yielded less than 49 bushels in 1917 might be discarded, the chances being 21 to 1 that all discarded sorts were lower yielders than II-17-7.

In obtaining a discard figure for the average of several years the average probable error is multiplied by 3 and divided by the square root of the number of years in the test.

For convenience the discard figures are here listed. These have been computed separately for the two- and six-rowed sorts.

Year	6-rowed Bushels	2-rowed Bushels
1916	49.3	39.6
1917	49.0	40.6
1918	58.7	45.9
1916-18	51.7	40.9
1917-18	54.4	43.5

Applying this method to the yearly yields and averages eliminated many varieties from further consideration. Table III shows the sorts which remain after applying the elimination figure, the selections being arranged in the table in the order of their yield, the higher yielding sorts appearing first. This method is somewhat arbitrary; however, it has some mathematical foundation.

Of the sorts which have been tested for three years, South African × Manchuria, II-16-47, is the only selection which is not eliminated for some one crop season. All varieties which were eliminated by this method for two out of the three years have been discarded from further test.

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[8] The Interpretation of Experimental Results. In Jour. Agr. Sci., vol. 3, pt. 4, pp. 417-440. 1910.

TABLE III

SELECTIONS NOT ELIMINATED BY THE METHOD USED AND YIELDS PER ACRE FOR THESE SELECTIONS

1916 Results		1917 Results		1918 Results		1916-1918 Results		1917-1918 Results	
N. S. N.	Yield	N. S. N.	Yield	N. S. N.	Yield	N. S. N.	Yield	N. S. N.	Yield
6-rowed	Bu.	6-rowed	Bu.	6-rowed	Bu.	6-rowed	Bu.	6-rowed	Bu.
II-16-47	57.7	II-17-7	56.3	I-16-31	69.4	II-16-47	56.4	II-17-2	60.7
I-16-21	55.5	II-16-77	52.0	III-15-128	67.5	I-15-2	55.2	I-16-31	59.6
I-15-2	53.4	II-16-91	51.7	I-16-13	67.0	I-16-31	55.2	II-17-7	59.5
II-16-101	52.5	II-16-92	51.5	I-16-3	66.6	I-16-13	54.3	II-17-4	59.0
II-16-77	51.9*	II-17-8	51.1	I-15-2	66.6	II-16-91‡	50.0	I-16-13	56.6
I-16-61	51.4	II-16-47	50.5	II-17-1	64.5	III-15-128‡	51.0	I-15-2	56.2
III-15-130	51.2	II-17-2	67.8*	II-17-7	62.7	....	51.3	II-16-47	55.8
I-16-66	51.5*	II-17-4	60.4*	I-16-66	61.8	....	......	II-17-3	55.8
II-16-92	50.0	II-17-3	51.7	I-16-15	61.2	....	......	II-16-91	55.4
I-16-29	49.8	II-17-6	51.5	II-16-47	61.1	....	......	II-17-6	54.9
I-16-13	49.7	I-16-31	49.8	II-17-3	59.8	....	......	II-17-8	55.4
....	......	....	......	II-17-8	59.7	....	......	....	......
....	......	....	......	II-16-91	59.1	....	......	....	......
....	......	....	......	I-18-3	59.4	....	......	....	......
2-rowed	Bu.	2-rowed	Bu.	2-rowed	Bu.	2-rowed	Bu.	2-rowed	Bu.
I-16-40	45.5	II-16-37	47.9	II-18-1	56.6	I-16-40	45.9	II-17-19	49.3
III-15-121	45.8	II-17-22	43.9	II-17-19	55.1	II-16-37	45.5	II-16-37	46.8
I-16-59	43.8	I-16-40	43.2	II-18-5	55.0	I-16-61	44.4	II-17-23	46.7
II-16-37	43.0	II-16-78	41.1	II-16-131	54.0	II-16-78	43.2	I-16-40	46.2
I-16-61	51.4*	II-16-76	40.0	I-18-8	53.7	II-16-76	42.1	III-15-121	45.5
II-16-76	47.8	I-13-21	40.3	I-16-4	49.1	III-15-128	45.6	II-16-131	45.9
II-16-78	42.6	III-15-121	42.2†	III-15-121	48.8	III-15-121	45.5	II-17-21	44.2
....	......	II-17-23	49.8*	I-13-21	46.4	I-16-59	43.2	II-17-22	43.4
....	......	II-17-21	44.6*	II-16-78	45.9	....	......	II-16-78	43.5
....	......	II-17-19	43.4*	II-16-37	45.6	....	......	I-13-2	43.4
....	......	I-16-59	41.6*	....	......	....	......	....	......

* Single-plot test. † Two-plot test. ‡ Slightly below elimination figure.

Those 6-rowed sorts which survive by this method are as follows:

Name	N. S. N.	Year eliminated
South African × Manchuria..	II-16-47	....
South African × Manchuria..	II-16-77	1918
Manchuria	I-15-2	1917
Manchuria	I-16-66	1917
Lion × Featherston.........	II-16-91	1916
Lion × Featherston.........	II-16-92	1917
Lion	I-16-13	1917
Highland Chief	I-16-31	1916

Of these selections, I-16-31, Highland Chief, has been discarded from further test, as it is a weak-strawed variety and lodged very badly each year that it was grown. This leaves seven varieties which appear to deserve further trial in field plots.

Some sorts which have been tested for only two years, 1917 and 1918, show promise on a basis of yield. These are:

Name	N. S. N.	Average yield 1917-1918	Average per cent lodged	Average degree lodged
		Bushels		
Lion × Featherston	II-17-3	55.8	99	82
Lion × Manchuria	II-17-2	60.7	98	85
Lion × Manchuria	II-17-4	59.0	100	89
Bay Brewing × Lion	II-17-6	54.9	95	78
Lion × Mariout	II-17-7	59.5	100	90
South African × Manchuria	II-16-47	55.8	28	30
Manchuria Nos. 105 and 184	....	46.6	69	35

South African × Manchuria, II-16-47, and Manchuria are also listed in the table as a basis of comparison. These smooth-awned sorts appear very promising on a yield basis but unfortunately they have weak straw.

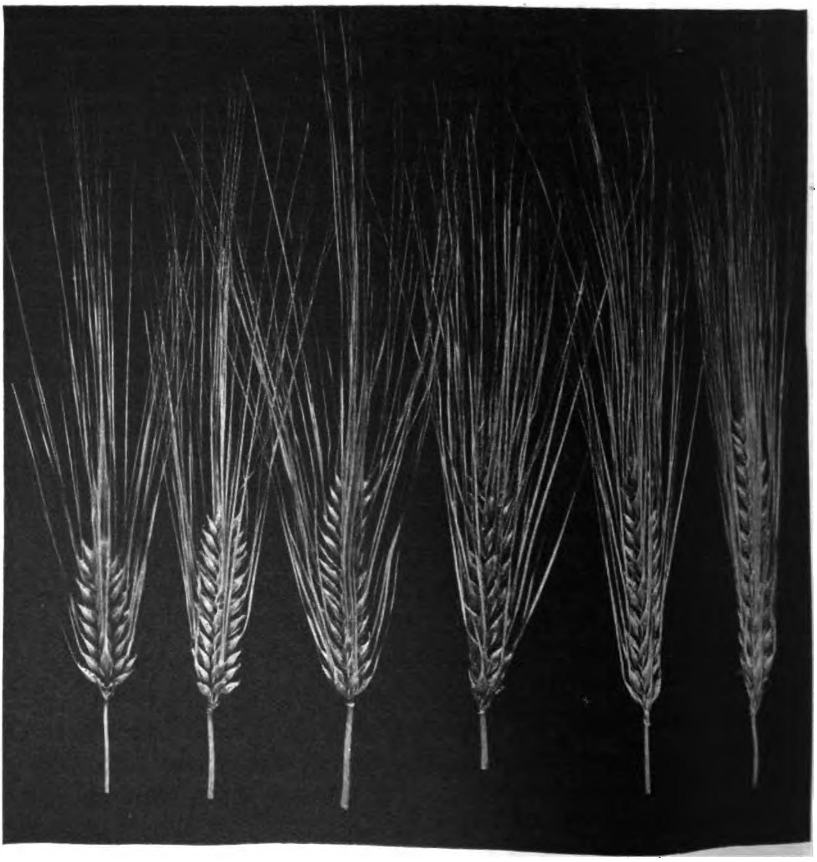

Fig. 14. Smooth-Awned Barleys of Different Types and Their Parents

From left to right: Mariout, N.S.N. I-15-130, 6-rowed, dense-headed, with rough awns; Lion × Mariout, II-17-9, 6-rowed, dense-headed, with smooth awns; Lion × Mariout, II-17-7, 6-rowed, near dense-headed, with smooth awns; Lion, I-16-13, 6-rowed, black, with smooth awns; Lion × Manchuria, II-16-91, 6-rowed with smooth awns; and Manchuria, Minn. Accession No

No two-rowed varieties survived the test when compared with six-rowed sorts. Several, however, performed sufficiently well that they deserve to be tested in sections of the state where two-rowed varieties are more promising. As selected on a yield basis these are:

Name	N. S. N.	Average yield 1916-1918	Average per cent lodged	Average degree lodged
		Bushels		
B. D. Bill	I-16-40	45.9	62	49
456 × Svanhals	II-16-37	45.5	47	40
C. I. 578	I-16-61	44.4	59	40
Bohemian × Manchuria	II-16-78	43.2	50	31
Bohemian × Manchuria	II-16-76	42.1	66	49
Lake City	I-16-59	43.2	70	58

On the basis of the lodging data it would seem that II-16-37 and II-16-78 deserve further trial.

PRELIMINARY TEST AT SUBSTATIONS

In 1918 several of the more promising sorts were grown in rod row tests at three substations. Three plots systematically distributed to overcome some of the effect of soil variability were used for each selection. Results are given in Table IV for average yield. Three smooth-awned barleys and the cross between South African and Manchuria, II-16-47, were compared with Minnesota Accession No. 105 and Minnesota No. 184. The smooth-awned barleys performed satisfactorily at University Farm and Waseca, but the results were not so favorable at Morris and Crookston. South African × Manchuria, II-16-47, proved about equal to the Manchuria sorts on the basis of average result. Since it stands up better than Manchuria it seems of considerable promise for it has been a consistent yielder each year at University Farm. These substation results show that it has yielding ability under different environmental conditions.

TABLE IV

TEST AT SUBSTATIONS IN 1918*

Name	N. S. N.	Yield per acre				
		U. Farm	Waseca	Morris	Crookston	Average
		Bushels	Bushels	Bushels	Bushels	Bushels
Lion × Manchuria	II-16-92	42.3	49.0	41.0	54.5	46.7
Lion × Manchuria	II-16-91	59.1	45.8	42.0	52.5	49.9
Lion × Manchuria	II-17-1	64.5	48.4	29.1	31.3	43.3
S. African × Manchuria	II-16-47†	61.1	50.8	54.0	64.7	57.7
Manchuria	Minn. No. 105	53.1	50.6	59.0	66.5	57.3
Manchuria	Minn. No. 184	54.6	41.7	64.4	77.7	59.6
456 × Svanhals	II-16-37†	45.6	33.5	54.9	77.3	52.8
Chevalier	Minn. No. 230	35.6	32.9	36.9	63.3	42.2

* Acknowledgment is made of the coöperation in these tests of Albert Hoversten, at Waseca; P. E. Miller, at Morris; and C. G. Selvig and Roy Westley, at Crookston.

† The Experiment Station has decided to increase and distribute South African × Manchuria, II-16-47, under the name Minsturdi, Minn. No. 439, and 456 × Svanhals, II-16-37, as Svansota, Minn. No. 440.

456 × Svanhals, II-16-37, proved superior to Chevalier, the pedigreed two-rowed barley which the station has grown for distribution. It gave especially good yields at Morris and Crookston.

The first two smooth-awned barleys listed in the table, South African × Manchuria and 456 × Svanhals, were tested in field variety plots at University Farm in 1918.[4] Both smooth-awned barleys excelled in yield as compared with Minnesota No. 184, while South African × Manchuria and 456 × Svanhals gave slightly larger yields than No. 184, tho not significantly so. These results show that sorts which prove superior by row tests may also be expected to excel in field plot variety studies.

SUMMARY OF RESULTS

1. Some head selections of Manchuria barleys proved to be low yielders each of the years that they were grown, while others gave high yields each year.
2. Nearly as wide variations in yield were found when comparing head selections within a variety as were obtained by comparing different varieties.
3. Several smooth-awned sorts were compared with standard Minnesota types. The results show that smooth-awned barleys of high yielding ability can be obtained. Further work along this line is under way.
4. A cross between Manchuria and a low-yielding stiff-strawed sort, known as South African, has given two selections which have yielding ability and stiffer straw than the Manchuria parent.
5. Results reported show the necessity of testing a new production in various localities of the state before recommending its general introduction.

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[4] These plot tests are under the direction of A. C. Arny, who is in charge of the section of farm crops.

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The University of Minnesota

AGRICULTURAL EXPERIMENT STATION

FIRST GENERATION CROSSES BETWEEN STANDARD MINNESOTA CORN VARIETIES

TECHNICAL

BY

H. K. HAYES AND P. J. OLSON

DIVISION OF AGRONOMY AND FARM MANAGEMENT

UNIVERSITY FARM, ST. PAUL

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FIRST GENERATION CROSSES BETWEEN STANDARD MINNESOTA CORN VARIETIES

By H. K. HAYES and P. J. OLSON[1]

INTRODUCTION

The production of seed in corn results from the union of the male cell of the pollen grain of the tassel with the female cell at the base of the silk. Cross-fertilization results when this union occurs between cells of different plants, this being the general manner of seed formation in corn. While self-fertilization may take place, recent experiments have shown that the percentage is very small. (Waller 1917, Hayes 1918).

Two distinct lines of investigation have led to a somewhat critical attitude among plant breeders in regard to the present methods of corn breeding. One of these is the lack of relation (within a variety) between commonly accepted score card characteristics and resultant yield. This matter has been reviewed in a recent bulletin (Olson, Bull, and Hayes, 1917). The second line of investigation has given a rather large body of evidence which shows that yield in corn is closely related to the heterozygous condition. This is shown by the fact that the highest yield has often been obtained in first generation crosses between varieties or strains which differ considerably in their inherent characteristics.

These investigations have led to an attack upon the following questions, the solution of which will be of material benefit to the corn breeder.

1. What method of seed selection should be practiced by the farmer and seed corn specialist to obtain highest yields?[2]

2. Will the isolation of pure types by self-fertilization, the determination of which of these when crossed give highest yields, and the production of such crossed seed, be of enough value to pay for the expense of the work?[3] Another point to this line of attack presents itself, namely, the value of eliminating undesirable traits by self-fertilization and the production of an improved variety from a cross between selfed lines, which are pure for certain desired characters.

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[1] Resigned as assistant agronomist, June, 1918.

[2] Two rather easy methods of selection were outlined in a recent publication of this station (see Olson, Bull, and Hayes, 1917), now out of print.

[3] For a discussion of this subject the reader is referred to Shull 1910, East and Hayes 1912, Jones 1918.

3. Will first generation crosses between varieties give as high yields as crosses between selfed sorts? Will they pay for the extra trouble of producing first generation seed?

The purpose of this paper is to give four years' data on first generation crosses between standard Minnesota varieties.

REVIEW OF SOME PREVIOUS INVESTIGATIONS

Numerous studies—among which may be mentioned Morrow and Gardener 1893, 1894; Collins 1910; Hayes and East 1911; Hartley et al 1912; Hayes 1913; Jones et al 1916; and Hutcheson and Wolf 1917—have given conclusive evidence that first-generation crosses will, on the average, yield more than the average of the parents used in making the cross. All crosses are not equally desirable and often a small percentage give lower yields than the average of their parents. As a fair illustration of the usual results, the work at the Connecticut station may be cited. This was a comparison of fifty first-generation crosses, several of which were tested for two or more seasons with their parents. Of these, 88 per cent yielded more than the parental average and 66 per cent yielded more than either parent. Another fact of interest was that a cross yielded more than any of the parents each year of the test, the largest increases being obtained with flint-dent crosses. Of considerable significance was the result that crosses between high yielding parents gave as large percentage increases as crosses between lower yielding varieties.

Most of the previous investigations have dealt with a large number of crosses, and the results, while showing the value of the method, do not determine the comparative value of particular crosses and their parents for more than a single season. The results here reported are for several seasons and the question of seasonal variations is therefore attacked.

VARIETIES OF CORN USED

The crosses have been chiefly between standard-bred varieties, seed of these being obtained from corn growers who have been making a specialty of a particular sort and therefore have seed available each year.

For the 1915 test the seed was obtained from crosses made by A. C. Arny of the Section of Farm Crops. Seed for the flint and flour varieties was from the same source in 1915 as in later years. In 1915 Murdock, Rustler, and Silver King were not obtained from the same farmers who supplied it in other years. As the results are similar they have been placed together in the tables.

Minnesota No. 13 has been used as the male parent, the stock being the same as that grown for distribution. As the crosses have given very favorable results, it seems likely that this is partly due to the manner in which this variety has been bred. A brief statement of facts regarding the varieties used is here made.

Minnesota No. 13.—Originally obtained from a St. Paul seed company in 1893. For the last ten years a type plot has been grown annually. Seed for this type plot has been selected each year, only ears of desirable type and vigor being used for the type plot the following year. Good seed from the type plot has been used for multiplication and distribution. Male parental seed used in making the crosses here reported has been grown and selected from this type plot.

Rustler, white dent.—Original seed obtained through the coöperation of J. I. Swedberg, Cokato, Minn. Since 1915 it has been grown at University Farm and selected each fall before a killing frost from vigorous stalks in hills having a perfect stand.

Silver King, white dent.—Obtained yearly from John Henderson, Cokato.

Chowen's Yellow Dent.—Obtained from D. F. Chowen, Wayzata.

Blue Soft.—A blue aleurone soft or flour corn obtained from a farmer in South Dakota. He no longer grows this variety and no stock of this seed is now available.

King Phillip.—A red pericarp flint obtained from Northrup King & Co. No selection except for purity is practiced.

Longfellow.—A long-eared yellow flint from Northrup King & Co.

Another strain known as Burwell's Longfellow has been used. It was obtained from E. E. Burwell of New Haven, Conn., and has a record of being one of the better yielding flints tested at the Connecticut station.

Smut Nose.—A yellow flint with a reddish tinge to the pericarp toward the tip of the ear, obtained from Northrup King & Co.

Mercer.—A twelve-rowed yellow flint obtained from H. M. Miller, Big Lake, Minn.

METHOD OF MAKING CROSSES AND CARRYING OUT TESTS

Seed of the varieties used, except as noted, has been obtained from the same source each year. Two-year-old seed has also been kept on hand in order to insure having a supply.

The crosses have been made on an isolated plot, Minnesota No. 13 being grown every other row. All varieties except No. 13 were detassled before the pollen was mature, seed from these detasseled stalks being used to grow the first generation crosses.

In making the test for yield a four-row plot has been used, 37 hills being planted per row. Several extra seeds have been planted in each hill and later these have been thinned to a stand of three stalks per hill.

The corn has been planted in the following order:

Longfellow
Longfellow × No. 13
Minnesota No. 13
Rustler × No. 13
Rustler

Each cross and parent, except as noted for 1916, has been grown in two plots, the two central rows of each plot being used for the computations. The results presented later are an average of the data obtained in two plots.

Some criticism of previous studies has been made on the ground that unadapted varieties were used for the tests and that two-year-old seed was also often used for the female parents. In our work this criticism does not hold, for the varieties obtained from farmers have yielded as well on the average as those grown from University Farm seed. In general, varieties have been obtained from farmers in the neighborhood of University Farm.

ONE- VERSUS TWO-YEAR-OLD SEED

For some varieties of which seed was obtained yearly from the same farmer, a comparison of the yielding value of one- and two-year-old seed was made. This was done in order to determine whether results from two-year-old seed were a reliable index of the yielding value of the variety and because criticisms have sometimes been made of studies of first generation crosses where two-year-old seed has been used for the female parent.

A part of the variation (see Table I) as obtained by this comparison is very probably due to the fact that in 1915 and 1917 the seasons were very decidedly unfavorable for corn.

As has already been mentioned, several extra seeds were planted in each hill and by thinning to three stalks fairly good stands were obtained. Corrections were made for missings hills but none were attempted for missing stalks.

The stands for the 1916 and 1917 tests were fairly good and in 1918 as nearly perfect stands were obtained as could be expected in field plot tests. For the 1916 test, two out of the three varieties gave larger yields from two-year-old seed. This is very likely due to the unfavorable season in 1915. In 1917 one-year-old seed proved better than two-year-old for two varieties and similar yields for one- and two-year-old seed were obtained from another variety. Two tests of one-

and three-year-old seed were made, the yields being about the same for one variety and higher in the other test for the one-year-old seed. In 1918 yields of one- and two-year-old seed were compared for three varieties, the two-year-old seed giving higher yields in all three cases.

TABLE I

COMPARISON OF ONE- AND TWO-YEAR-OLD SEED

Variety	Year seed saved	Year of test	Yield per acre
			Bushels
No. 23	1914	1916	40.1
No. 23	1915	1916	37.9
Chowen's Yellow Dent	1914	1916	37.4
Chowen's Yellow Dent	1915	1916	41.5
Silver King	1914	1916	42.6
Silver King	1915	1916	40.7
No. 23	1915	1917	20.2
No. 23	1916	1917	20.7
Mercer	1915	1917	21.6
Mercer	1916	1917	23.6
Silver King	1915	1917	19.8
Silver King	1916	1917	22.5
Chowen's Yellow Dent	1914	1917	18.9
Chowen's Yellow Dent	1916	1917	20.9
Murdock	1914	1917	15.7
Murdock	1916	1917	15.8
Mercer	1916	1918	44.5
Mercer	1917	1918	43.5
Silver King	1916	1918	51.9
Silver King	1917	1918	44.8
Murdock	1916	1918	50.1
Murdock	1917	1918	46.3

These results indicate that two-year-old seed, when correctly stored, may be expected to yield as well as one-year-old seed. The results also show that well ripened two-year-old seed is superior to one-year-old seed which is not so well matured, altho both sorts give good stands.

COMPARISON OF CROSSES AND PARENTS

YIELD

The yields as given in Table II are a comparison for the crosses and parents on a shelled corn basis. All ear corn from each plot was weighed when husked and a sample of from 30 to 50 pounds saved in a corn crate. These samples were then stored until January, when they were reweighed and shelled. The yields as given represent the amount of actual shelled corn produced, on an acre basis.

Yearly and average yields are listed in the table, each such yield (except as noted for 1916) being an average of the results from two plots, the first-generation crosses being grown between their parents.

As the outer rows of each plot are discarded, the factor of competition between different varieties is eliminated. The crosses and parents are also compared on a percentage basis, the yield of Minnesota No. 13, which was grown in a plot adjacent to each first-generation cross, being considered as 100.

TABLE II

Comparative Yields of First Generation Crosses and Parents, 1915 to 1918 inclusive

Variety	Yield in bushels per acre					Per cent yield No. 13 as 100	Cross minus parent average	Cross minus better parent
	1915	1916*	1917	1918	Average			
No. 13	21.8	54.2	....	47.9	41.3	100.0		
King Phillip	25.9	53.9	....	43.8	41.2	100.0		
Cross	32.6	63.3	....	52.6	49.5	119.9	19.9	19.9
No. 13	21.8	54.2	22.9	47.9	36.7	100.0		
Longfellow (NK)	29.8	48.1	22.1	47.4	36.9	100.5		
Cross	42.4	52.5	22.9	57.6	43.9	119.6	19.3	19.1
No. 13	....	....	22.9	47.9	35.4	100.0		
Burwell's Longfellow	....	....	21.2	52.3	36.8	104.9		
Cross	....	....	25.4	55.4	40.4	114.1	11.6	9.2
No. 13	....	....	22.1	52.0	37.1	100.0		
Mercer	....	....	23.6	44.5	34.1	91.8		
Cross	....	....	22.7	49.5	36.1	97.3	1.4	—2.7
No. 13	23.7	45.1	....	....	34.4	100.0		
Smut Nose	31.1	45.1	....	....	38.1	110.8		
Cross	32.3	55.4	....	....	43.9	127.6	22.2	16.8
No. 13	26.8	45.1	....	....	36.0	100.0		
Blue Soft	27.3	42.3	....	....	34.8	96.7		
Cross	37.5	57.8	....	....	47.7	132.5	34.1	32.5
No. 13	23.7	38.7	20.6	52.1	33.8	100.0		
No. 23	29.1	40.1	20.7	41.4	32.8	96.7		
Cross	36.4	42.8	23.8	47.1	37.5	110.9	11.5	10.9
No. 13	27.3	....	....	....	27.3	100.0		
N. W. Dent	28.9	....	....	....	28.9	105.9		
Cross	31.6	....	....	....	31.6	115.7	12.7	9.8
No. 13	20.2	34.1	22.1	52.1	32.1	100.0		
Rustler	25.0	42.5	22.8	53.7	36.0	112.1		
Cross	26.7	45.1	22.7	49.9	36.1	112.4	6.3	0.3
No. 13	25.6	38.2	23.0	49.1	34.0	100.0		
Silver King	20.7	42.1	22.5	51.9	34.3	100.9		
Cross	25.8	46.8	20.2	52.3	36.3	106.7	6.2	5.8
No. 13	25.6	38.2	....	49.1	37.6	100.0		
Murdock	16.9	33.6	....	50.1	30.2	80.3		
Cross	21.3	44.2	....	49.2	38.2	101.6	11.4	1.6
No. 13	....	36.3	22.7	....	29.5	100.0		
Chowen's Yellow	....	37.4	20.9	....	29.2	99.0		
Cross	....	46.9	20.9	....	33.9	114.9	15.4	14.9

* Crosses of King Phillip, Longfellow (NK), Smut Nose, Blue Soft with No. 13 and their parents were only tested in a single plot each. The female parent and the cross were grown from seed similar to that used in 1915.

The cross between King Phillip and No. 13 yielded more than either parent each of the three years that it was tested, giving an average of 19.9 per cent more corn than the higher yielding parent.

Northrup King's Longfellow × No. 13 cross was tested for all four years and yielded more than the better parent in 1915 and 1918; the same as the higher yielding parent in 1917; and more than the parental average in 1916. As an average of the four years' test, this cross yielded 19.1 per cent more corn than its better parent.

Mercer × No. 13 gave an increase of 1.4 per cent over the average of its parents and yielded 2.7 per cent less than the No. 13 parent. This cross was tested in 1917 and 1918, and is not an advantageous one.

Smut Nose × No. 13 was tested in 1915, 1916, and 1918, the cross exceeding either parent each of the three seasons, giving 16.8 per cent more corn than the better parent.

Blue Soft × No. 13 was tested only two years and in 1916 only in a single plot test. This seems to be a very advantageous cross, exceeding the better parent by 32.5 per cent.

Three first-generation crosses between other dents and No. 13 have been tested for all four seasons. No. 23 × No. 13 exceeded the better parent by 10.9 per cent, and the cross between Silver King and No. 13 gave 5.8 per cent increase over the higher yielding parent. Rustler White Dent, which has been bred at University Farm since 1915, yielded somewhat more than No. 13 for each of the four years. The cross gave about the same yield as the Rustler parent. On a percentage basis, the Rustler is exceeded by the crosses of No. 13 with each of the following varieties, Longfellow, King Phillip, and Smut Nose. Murdock × No. 13, which was tested for three years, exceeded the average of its parents by 11.4 per cent and gave 1.6 per cent more corn than the No. 13 parent, and Chowen's Yellow Dent crossed with No. 13 exceeded the better parent by 14.9 per cent.

Six flint-dent crosses have been compared with their parents, the period of test being from two to four years, the crosses giving 15.8 per cent more corn than the average of the higher yielding parents.

Five dent crosses have been similarly tested, the crosses averaging 6.7 per cent more than the higher yielding parent.

MATURITY

Aside from yield the most important characteristic for corn in Minnesota is that of early maturity. The crosses may therefore be profitably compared with their parents for this character. Three methods of determining comparative maturity have been used: date of tasseling; date of maturity, that is, denting for the dents and glazing for the flints; and comparative shrinkage after husking.

DATE OF TASSELING

Averages for date of tasseling are given in Table III, twelve crosses being compared with their parents. In general, maturity is of intermediate condition, altho the crosses average 1.4 days earlier than the parental average. Increase in earliness of the crosses as compared with the parental average is greater in some cases than in others. Blue Soft × No. 13 and Northwestern Dent × No. 13 seem to be crosses of this nature altho the results are for only two years in the case of Blue Soft × No. 13 and for a single season in the case of Northwestern Dent × No. 13.

TABLE III

DATE OF TASSELING OF FIRST GENERATION CROSSES AND PARENTS, 1915 TO 1918 INCLUSIVE

Variety	Date of tasseling					Average of parents minus cross
	1915	1916	1917	1918	Average	
No. 13	8-10	7-29	....	7-26	8- 1	
King Phillip	8- 7	7-27	....	7-26	7-30	
Cross	8- 7	7-29	....	7-24	7-30	+1.0
No. 13	8-10	7-29	8-6	7-26	8- 2	
Longfellow (NK)	8- 6	7-29	8-3	7-24	7-31	
Cross	8- 7	7-29	8-6	7-25	8- 1	0.0
No. 13	....	....	8-6	7-26	8- 1	
Burwell's Longfellow	....	....	8-5	7-25	7-31	
Cross	....	....	8-4	7-26	7-31	+0.5
No. 13	....	....	8-7	7-26	8- 2	
Mercer	....	....	8-5	7-26	8- 1	
Cross	....	....	8-4	7-25	7-31	+1.5
No. 13	8-10	8- 2	....	....	8- 6	
Smut Nose	8- 6	7-29	....	....	8- 2	
Cross	8- 7	7-29	....	....	8- 3	+1.0
No. 13	8-11	8- 2	....	....	8- 7	
Blue Soft	8- 8	8- 4	....	....	8- 6	
Cross	8- 7	8- 1	....	....	8- 4	+2.5
No. 13	8-10	8- 1	8-7	7-26	8- 3	
No. 23	8- 3	7-27	8-1	7-21	7-29	
Cross	8- 5	7-30	8-2	7-23	7-31	+1.0
No. 13	8-11	....	....	....	8-11	
Northwestern Dent	8- 5	....	....	....	8- 5	
Cross	8- 6	....	....	....	8- 6	+2.0
No. 13	8-13	8- 1	8-7	7-26	8- 4	
Rustler	8-13	8- 2	8-7	7-27	8- 5	
Cross	8-13	8- 1	8-5	7-26	8- 4	+0.5
No. 13	8-11	8- 1	8-7	7-26	8- 4	
Silver King	8-15	8- 2	8-8	7-28	8- 6	
Cross	8-12	8- 2	8-7	7-25	8- 4	+1.0
No. 13	8-11	8- 1	....	7-26	8- 2	
Murdock	8-15	8- 5	....	7-29	8- 6	
Cross	8-13	8- 2	....	7-26	8- 3	+1.0
No. 13	....	8- 1	8-7	....	8- 4	
Chowen's Yellow	....	8- 2	8-7	....	8- 5	
Cross	....	8- 2	8-7	....	8- 5	+0.5

DATE OF MATURITY

Date of maturity is a difficult note to take. Results as obtained indicate, as with the note for date of tasseling, that the crosses mature slightly earlier than the parental average. King Phillip × No. 13, which was tested for the two favorable corn years, 1916 and 1918, matured in 1916 two days earlier than King Phillip and in 1918 as early as King Phillip. It was four days earlier in maturity than Minnesota No. 13 in 1916 and five days earlier in 1918. The Mercer × No. 13 cross, which gave only a slight increase in yield over the parental average and produced 5 per cent more shelled corn than Mercer, matured as early as the Mercer parent both years in which it was tested, being 5 and 3 days earlier in maturity in 1917 and 1918, respectively, than Minnesota No. 13.

Nine crosses were compared with their parents for two and three years. Of these, six matured from 1 to 3 days earlier than the parental average, one 1 day later than the parental average, and two the same day as the parental average.

TABLE IV

DATE OF MATURITY OF FIRST-GENERATION CROSSES AND PARENTS, 1916 TO 1918 INCLUSIVE

Variety	1916	1917	1918	Average	Average of parents minus cross
No. 13	9-8	....	9-3	9-6	
King Phillip	9-6	....	8-29	9-2	
Cross	9-4	....	8-29	9-1	+3
No. 13	9-8	9-27	9-3	9-13	
Longfellow (NK)	9-6	9-23	8-30	9-9	
Cross	9-7	9-25	9-3	9-12	−1
No. 13	....	9-27	9-3	9-15	
Burwell's Longfellow	....	9-27	9-3	9-15	
Cross	....	9-26	9-3	9-15	0
No. 13	....	9-26	9-2	9-14	
Mercer	....	9-21	8-30	9-10	
Cross	....	9-21	8-30	9-10	+2
No. 13	9-12	9-26	9-3	9-14	
No. 23	9-5	9-19	8-26	9-6	
Cross	9-7	9-20	8-29	9-8	+2
No. 13	9-12	9-26	9-3	9-14	
Rustler	9-12	9-25	9-3	9-13	
Cross	9-10	9-23	9-3	9-12	+2
No. 13	9-13	9-26	9-3	9-14	
Silver King	9-17	9-30	9-6	9-18	
Cross	9-14	9-27	9-5	9-15	+1
No. 13	9-13	....	9-3	9-8	
Murdock	9-19	....	9-8	9-14	
Cross	9-16	....	9-5	9-11	0
No. 13	9-12	9-26	....	9-19	
Chowen's Yellow	9-15	9-29	....	9-22	
Cross	9-12	9-25	....	9-19	+2

PER CENT SHRINKAGE

As has already been explained, a sample of from 30 to 50 pounds was weighed at husking, stored until January of the following year, and then reweighed. Per cent shrinkage as obtained by this test seems a reliable comparison of degree of maturity of crosses and parents.

Three years' results are presented in Table V. These are for the favorable corn years of 1916 and 1918 and the unfavorable season of 1915.

TABLE V

PER CENT SHRINKAGE OF FIRST-GENERATION CROSSES AND PARENTS, 1915, 1916, AND 1918

Variety	Per cent shrinkage				Cross minus average of parents
	1915	1916	1918	Average	
No. 13	59	22	34	38	
King Phillip	44	21	42	36	
Cross	46	23	33	34	+3
No. 13	59	22	34	38	
Longfellow (NK)	41	21	32	31	
Cross	35	25	33	31	+4
No. 13	55	23	...	39	
Smut Nose	38	17	...	28	
Cross	44	23	...	34	0
No. 13	55	23	...	39	
Blue Soft	53	38	...	46	
Cross	52	29	...	41	+2
No. 13	62	22	...	42	
Pride of North	62	17	...	40	
Cross	40	21	...	31	+10
No. 13	55	22	36	38	
No. 23	31	24	29	28	
Cross	39	21	32	31	+2
No. 13	62	23	36	40	
Rustler	59	19	33	37	
Cross	56	21	34	37	+2
No. 13	55	22	33	37	
Silver King	70	25	39	45	
Cross	57	26	36	40	+1
No. 13	55	22	33	37	
Murdock	63	29	38	43	
Cross	70	27	36	44	−4

The results are particularly noticeable for the 1915 test, in which very large shrinkage per cents were obtained. The Minnesota No. 13 parent gave an average shrinkage of 57 per cent, the female parents averaged 51 per cent, and the crosses 48 per cent. The differences for the 1916 and 1918 tests were very small, probably because nearly all varieties matured these years. On an average seven of the nine varieties gave from 1 to 10 per cent less shrinkage than the parental average, one the same shrinkage as the parental average, and one 4 per cent more than the parental average.

HEIGHT IN INCHES OF CROSSES AND PARENTS

One measure of the added stimulus to development from crossing which is a fairly reliable index of growth vigor is average height of plants. Results for those crosses which have been tested for from two to four years are presented in Table VI.

TABLE VI

HEIGHT OF FIRST-GENERATION CROSSES AND PARENTS, 1915 TO 1918 INCLUSIVE

Variety	Average height					Average of parents minus cross
	1915	1916	1917	1918	Average	
	In.	In.	In.	In.	In.	In.
No. 13	98	96	...	95	96	
King Phillip	85	81	...	92	86	
Cross	97	96	...	96	96	+5
No. 13	98	96	90	93	94	
Longfellow (NK)	87	86	88	89	88	
Cross	94	96	93	98	95	+4
No. 13	...	...	90	93	92	
Burwell's Longfellow	...	...	90	95	93	
Cross	...	...	95	103	99	+6
No. 13	...	...	90	90	90	
Mercer	...	...	83	89	86	
Cross	...	...	90	96	93	+5
No. 13	96	96	...	...	96	
Smut Nose	84	78	...	...	80	
Cross	93	92	...	...	93	+5
No. 13	97	96	...	...	97	
Blue Soft	88	86	...	...	87	
Cross	95	92	...	...	94	+2
No. 13	96	86	86	92	90	
No. 23	70	82	70	80	76	
Cross	85	83	83	87	85	+2
No. 13	89	86	90	92	89	
Rustler	99	88	96	97	95	
Cross	98	88	94	96	94	+2
No. 13	92	89	91	92	91	
Silver King	97	89	100	97	96	
Cross	95	84	93	93	91	−3
No. 13	92	91	...	92	92	
Murdock	98	90	...	95	94	
Cross	98	90	...	94	94	+1
No. 13	...	84	91	...	88	
Chowen's Yellow	...	88	93	...	91	
Cross	...	87	91	...	89	−1

Five crosses between Minnesota No. 13 and flint varieties have been compared with their parents for height. The crosses averaged 5 inches taller than the average of the parents. For the King Phillip × No. 13 cross, the average height of King Phillip for three years was 86 inches, for the No. 13 parent and the cross, 96 inches. The cross between Burwell's Longfellow and No. 13 was six inches taller than the average of the parents. This is of interest, for in this cross both parents were about the same height.

Of five crosses between Dents and No. 13, three slightly exceeded the parental average and two were slightly lower than the average height of the parents. These results are a further indication that crosses between dents are less likely to give increases than flint-dent crosses.

SHELLING PERCENTAGE OF CROSSES AND PARENTS

Shelling percentage has been obtained from the 1916 and 1918 samples which were saved to determine shrinkage. Only those varieties and crosses which were grown these two favorable seasons have been given in the table, results for each year, average results, and the comparison of the crosses with their parental averages being listed.

TABLE VII

SHELLING PERCENTAGE OF FIRST-GENERATION CROSSES AND PARENTS, 1916 AND 1918

Variety	Shelling percentage			Cross minus average of parents
	1916	1918	Average	
No. 13	83.2	83.0	83.1	
King Phillip	83.5	83.1	83.3	
Cross	83.3	83.5	83.4	+0.2
No. 13	83.2	83.0	83.1	
Longfellow (NK)	85.1	85.1	85.1	
Cross	84.6	84.7	84.7	+0.6
No. 13	82.9	83.5	83.2	
No. 23	87.8	86.3	87.1	
Cross	85.1	84.9	85.0	−0.2
No. 13	82.6	83.5	83.1	
Rustler	82.9	82.6	82.8	
Cross	82.8	83.2	83.0	0.0
No. 13	82.3	83.4	82.9	
Silver King	83.2	83.7	83.5	
Cross	84.6	83.6	84.1	+0.9
No. 13	81.6	83.4	82.5	
Murdock	81.2	84.5	82.9	
Cross	82.7	83.7	83.2	+0.5

The shelling percentage of the parental sorts is of some interest. King Phillip, for example, averaged 83.3 per cent, the seasonal variation being very small. Longfellow gave 85.1 shelling percentage both years. Of the Dent parental sorts, Minnesota No. 13 gave fairly comparable results in all tests with about the same shelling percentage as Rustler, Murdock, and Silver King. Minnesota No. 23 gave the highest shelling percentage of any sort tested, or 87.1. This is an early smooth dent and it shows that smooth dents of high shelling ability can be produced.

Of the six crosses, four gave slightly higher shelling percentages than the parental average, one the same as the parental average, and one slightly less than the average of the parents. The crosses averaged 0.33 per cent higher in shelling ability than the average of the parent.

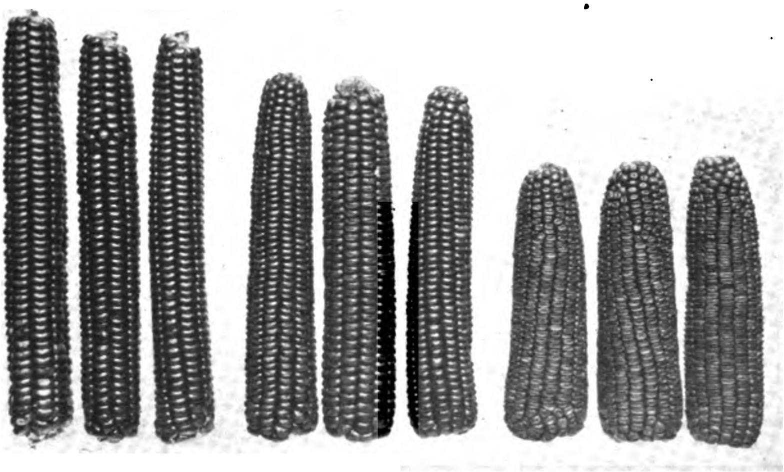

Fig. 1. At Left, Longfellow (N. K. & Co.); at Right, Minn. No. 13; in Center, First-Generation Cross

As an average of a four-years' test, the Longfellow and Minn. No. 13 gave practically the same yield. The cross exceeded either parent by an average of 19.3 per cent.

COMPARATIVE EAR LENGTH

The crosses were compared for ear length with their parents for the 1916 and 1918 tests. Table VIII gives the number of ears measured each year and the mean length.

Of the five flint-dent crosses, all were significantly of higher ear length than the average of the parents except the cross between Mercer and No. 13. The cross between Blue Soft and No. 13 was tested only in 1916. It behaved similarly to the flint-dent crosses. The four crosses between No. 13 and other dents gave the same ear length as the average of the dent parents in two tests and slightly higher ear length in the other two tests. These results are a further proof that crosses between dents and flints may be expected to give greater increases than dent-dent crosses.

TABLE VIII

LENGTH OF EARS OF FIRST-GENERATION CROSSES AND PARENTS, 1916 AND 1918

Variety	1916		1918		Average length of ear	Cross minus parental average
	Ears measured	Mean	Ears measured	Mean		
		In.		In.	In.	
No. 13	318	7.6	99	6.6	7.1	
King Phillip	50	9.4	100	9.1	9.3	
Cross	50	9.4	100	8.2	8.8	+0.6
No. 13	318	7.6	99	6.6	7.1	
Longfellow (NK)	50	10.9	103	9.9	10.4	
Cross	50	9.6	100	8.9	9.3	+0.5
No. 13	...	...	99	6.6	...	
Burwell's Longfellow	...	...	105	8.8	...	
Cross	...	...	101	8.4	...	+0.7
No. 13	318	7.6	...	...	...	
Smut Nose	50	9.8	...	...	...	
Cross	49	9.3	...	...	...	+0.6
No. 13	...	...	100	6.6	...	
Mercer	...	...	150	8.8	...	
Cross	...	...	102	7.8	...	+0.1
No. 13	318	7.6	...	...	...	
Blue Soft	50	10.0	...	...	...	
Cross	50	9.6	...	...	...	+0.8
No. 13	318	7.6	101	6.4	7.0	
No. 23	42	7.3	102	6.4	6.9	
Cross	97	7.6	101	6.9	7.3	+0.3
No. 13	318	7.6	101	6.4	7.0	
Rustler	97	8.2	100	7.2	7.7	
Cross	51	8.2	97	6.9	7.6	+0.2
No. 13	318	7.6	101	6.4	7.0	
Silver King	81	7.9	150	7.2	7.6	
Cross	104	7.8	100	6.7	7.3	0.0
No. 13	318	7.6	101	6.4	7.0	
Murdock	45	8.2	196	7.0	7.6	
Cross	98	7.8	98	6.8	7.3	0.0

AVERAGE ROWS PER EAR OF CROSSES AND PARENTS

The results for average rows per ear of the crosses and parents are given in Table IX, between 100 and 200 ears being used for each determination.

The crosses behave in a different way for this character than for any other one studied. It is commonly recognized that no flint varieties with a very high number of rows per ear are known, altho there are a few which average from 14 to 16 rows.

TABLE IX

AVERAGE NUMBER OF ROWS PER EAR OF FIRST-GENERATION CROSSES AND PARENTS, 1916 AND 1918

Variety	Average rows per ear, 1916	Average rows per ear, 1918	Average 1916 and 1918	Cross minus parental average
No. 13	15.3	16.1	15.7	
King Phillip	8.0	8.3	8.2	
Cross	11.5	11.6	11.6	−0.4
No. 13	15.3	16.1	15.7	
Longfellow (NK)	8.0	8.0	8.0	
Cross	11.8	11.3	11.6	−0.3
No. 13	....	16.1	....	
Burwell's Longfellow	....	8.0	....	
Cross	....	11.2	....	−0.9
No. 13	15.3	....	....	
Smut Nose	8.3	....	....	
Cross	11.4	....	....	−0.4
No. 13	....	16.7	....	
Mercer	....	12.8	....	
Cross	....	14.1	....	−0.7
No. 13	15.3	....	....	
Blue Soft	10.8	....	....	
Cross	11.9	....	....	−1.2
No. 13	15.3	15.8	15.6	
No. 23	12.6	12.2	12.4	
Cross	14.2	14.2	14.2	+0.2
No. 13	15.3	15.8	15.6	
Rustler	14.4	15.2	14.8	
Cross	15.3	15.3	15.3	+0.1
No. 13	15.3	15.8	15.6	
Silver King	15.5	16.3	15.9	
Cross	15.9	15.9	15.9	+0.1
No. 13	15.3	15.8	15.6	
Murdock	15.6	16.2	15.9	
Cross	16.3	15.7	16.0	+0.2

In the five flint-dent crosses as listed and for the Blue Soft × No. 13, the crosses average slightly lower in row number than the average of the parents. As all dent crosses average slightly higher than the average of the parents in row number, it seems likely that the results for the flint-dent crosses may be lower than the parental average, owing to some factor contributed by the flints which prevents high row number.

SUMMARY OF RESULTS

1. A comparison of one- and two-year-old seed of several varieties has been made. Well-matured two-year-old seed gave better yields than one-year-old seed saved in a season when corn did not thoroly mature, even tho equally good stands were obtained in both tests.

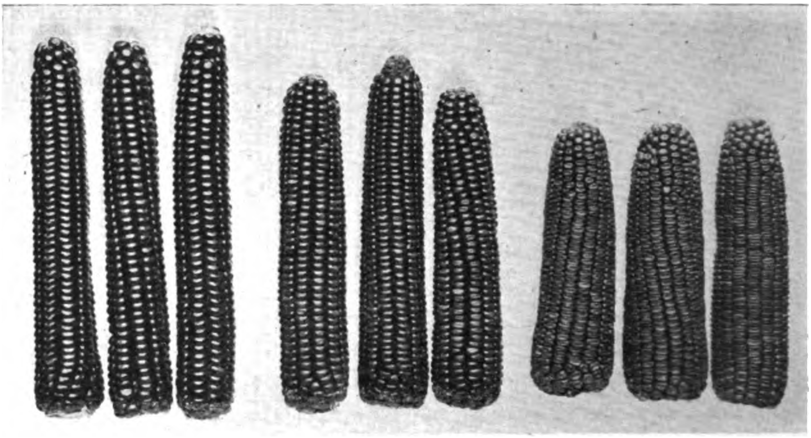

Fig. 2. At Left, King Phillip, a Red Pericarp Flint; at Right, Minn. No. 13; in Center, First-Generation Cross

The cross exceeded either parent in yield in each of three years in which it was tested and gave an average increase in yield of 19.9 per cent over each parent.

2. First-generation crossed seed may be produced by planting varieties in alternate rows and detasseling all of one variety before any of its pollen has matured, that is, as soon as the tassels appear.

3. Twelve first-generation crosses in which Minnesota No. 13 has been used as the male parent have been compared with their parents for yield of bushels of shelled corn per acre. Eleven crosses exceeded their better yielding parent from 0.3 to 32.5 per cent while one yielded 2.7 per cent less than the better parent.

4. The crosses and parents have also been compared for maturity, height of plant in inches, length of ear, shelling per cent, and number of rows per ear. In general the crosses are intermediate for these characters altho on an average the crosses exceed the parental average and occasionally exceed the better parent. One exception to this statement should be noted, as the row number of the flint-dent crosses was slightly less than the parental average.

5. In general, greater increases in yield were obtained from crosses between dents and flints or flours and dents than when both parents were dent varieties.

CAUSE OF VIGOR IN FIRST-GENERATION CROSSES IN RELATION TO CORN BREEDING

A rather recent hypothesis has been made by Jones (1917) (1918) to account for the vigor of first-generation crosses. It seems out of place in the present publication to discuss the relation of this explanation to former hypotheses. For an able discussion of this question the reader is referred to the work of Jones previously cited.

In accounting for the phenomenon of growth and development by the Mendelian method of explaining inheritance, it is considered that the vigor of each variety of corn is the result of certain inherited growth factors, these being somewhat different for varieties of unlike nature. On the Mendelian basis, in which these factors are located in particular chromosomes, it is impossible for a variety to be produced which is pure for all of the growth factors contributed by such different sorts as flints and dents. As each growth factor in the heterozygous condition, that is, when obtained from only a single parent, gives as a rule an increased development for the character in question over the parental average, it seems reasonable to conclude that a large part of the stimulus to development from crossing, named heterosis by Shull (1914), may be due to the partial dominance of linked growth factors.

These results have a bearing on methods of improvement of corn by selection. If vigor of growth and yield is greatest in first-generation crosses between different varieties, it seems reasonable to conclude that selection in corn should be on the basis of yield and that no close selection to type should be practiced.

In order to keep a variety in a vigorous condition it would seem that selection from vigorous stalks in perfect-stand hills would tend to keep up the heterozygous condition, providing no close selection to type of ear was practiced.

There is no reason for supposing that in order to obtain the highest yields it is necessary to grow a variety in which the seeds and cobs differ in color, but it does seem very likely that a close selection for such characters as row number, ear length, and plant type will eventually produce so pure a variety that some factors for growth vigor will be eliminated.

CONCLUSIONS

The use of first-generation crosses between pure varieties is a means of increasing yield in corn altho all such crosses are not equally productive, some being of no value.

Considerable increases from first-generation crosses between eight-rowed flints and Minn. No. 13 were obtained, the increased yields being sufficiently great to more than pay for the added cost of producing first generation seed.

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The University of Minnesota

AGRICULTURAL EXPERIMENT STATION

FARMERS' COÖPERATION IN MINNESOTA
1913-1917

BY

JOHN D. BLACK AND FRANK ROBOTKA

DIVISION OF RESEARCH IN AGRICULTURAL ECONOMICS

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FARMERS' COÖPERATION IN MINNESOTA
1913-1917

By JOHN D. BLACK AND FRANK ROBOTKA

INTRODUCTION

Since 1913 the Division of Research in Agricultural Economics has been collecting, under instructions received from the 1913 legislature, "statistics and information with reference to coöperative associations among farmers, and the management and methods of conducting such associations."[1] The results of these investigations have been published in the series of bulletins listed on the opposite page. All of these bulletins are available for general distribution among the people of the state. The purpose of this bulletin is to present the statistics of coöperation for 1917, and at the same time trace the changes in the coöperative movement in the state between 1913 and 1917. From these statistics certain important conclusions may be formed as to the reasons for the failure and success of various types of coöperative enterprises.

The statistics of coöperation for 1917 were mostly obtained, as in former years, by correspondence. About the usual number of companies failed to report, or their reports were so inaccurate and incomplete that they could not be used in the final averages. Enough coöperative companies reported, however, to make the results of interest and value. As in former years the statistics were collected in the same way, they can be readily compared from year to year. Some of the figures needed are collected annually by state officials, and in such cases the official records have been used.

The discussion of the causes of success or failure of coöperative enterprises is based in part upon questions included in the schedules sent out to the various companies, and in part upon first-hand experience with the accounting practices of a large number of coöperative companies.

In this bulletin, a company is considered coöperative if the farmers of the community largely own and control the business and divide most of its profits. According to strict use of the term, no company is coöperative unless it complies with the following three requirements: (1) Each member has one vote, regardless of the number of shares he owns; (2) no member owns more than a limited number of shares;

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[1] Chapter 386, Sess. Laws of 1913.

(3) the proceeds of the business are distributed on the basis of patronage, that is, according to the amount of purchases from or sales to the company, the dividend on shares being restricted to prevailing rates of interest for similar risks. However, many of the companies in Minnesota accomplish in other ways the purpose which is aimed at in these three requirements, and it is altogether fair and proper to consider them as coöperative. Their organization may be a little at fault, but the coöperative spirit is there or they could not succeed.

SUMMARY, 1913–1917

Table I gives the number of coöperative associations of each kind in 1913 and 1917, and their total volume of business. As later discussions will show, many of these figures are more or less estimates. They are in every case intended, however, to be underestimates, rather than overestimates. Most of the gain of 950 in the number of organizations is a real gain, and all of it is for important types of coöperation, except perhaps the gain of 350 for farmers' telephone companies. Besides, the number of coöperative telephone companies can be only a rough estimate. The important gains are those for livestock shipping associations, elevators, and creameries. The increase in miscellaneous organizations is largely because 100 buying clubs and 75 horse-breeding associations are included, many of which were probably in existence in 1913 but not counted. The real gain for the four years is therefore about 450, or 800 if farmers' telephone companies are included.

TABLE I
SUMMARY OF THE FARMERS' COOPERATIVE MOVEMENT IN MINNESOTA, 1913-1917

	Number of organizations		Annual volume of business	
	1917	1913*	1917	1913*
Creameries	643	613	$31,012,000	$21,676,252
Elevators†	360	270	45,000,000	24,000,000
Livestock shipping associations	400	115	33,000,000	6,000,000
Cheese factories	52	34	986,000	637,224
Stores	102	115	6,500,000	4,250,000
Potato warehouses	15	20	300,000	100,000
Fire insurance companies‡	159	154	712,606	696,732
Telephone companies	950	600	1,200,000	900,000
Miscellaneous	275	86	....	....
Total	2,950	2,000	$118,710,000	$58,260,000

* Data taken from Bulletin 146.
† Business arising from 1917 crop.
‡ Business of 1916.

Miscellaneous organizations include the following: Farmers' clubs doing coöperative buying, 100; horse-breeding associations, 75; breed associations, 28; county breeders' associations, 25; coöperative bull associations, 8; cow-testing associations, 15; farmers' lumber yards, 7; miscellaneous, 12.

The increase in volume of business is of course in large part due to the rise of prices. In the period between 1913 and 1917, retail prices rose 60 per cent in the United States, wholesale prices 75 per cent, farm products at wholesale, 88 per cent, and farm prices for Minnesota grains, 92 per cent. The rest of the increase is due to the increase in the number of companies. Only a few kinds of coöperative concerns have actually increased in size.

Minnesota leads all other states in the number of coöperative companies. Wisconsin is probably second, with 2,070 in 1916[2], not including 200 miscellaneous organizations such as are included in Table I. Of this number, only 471 are farmers' telephone companies. But leaving out farmers' telephones in both states and all miscellaneous associations, Minnesota had 330 more coöperative associations in 1917 than Wisconsin had in 1916. The third state is Iowa.

Minnesota's lead will undoubtedly be retained. For this three things are necessary: (1) Forming new coöperative organizations wherever and whenever local conditions make it possible for them to succeed. Those kinds of coöperation which succeed best should be tried first. (2) Making reasonably sure that local conditions are such that a new company will succeed, and then organizing the right kind of association. (3) Improving the organization and management of the existing companies so as to make sure that few of them fail. The new companies that never get a good start and the old ones that fail do the coöperative movement much harm.

ESSENTIALS TO SUCCESSFUL COÖPERATION

The division of Research in Agricultural Economics, after having studied coöperation in Minnesota for five years, feels that no one thing seems to be absolutely necessary to successful coöperation. It has found many things, however, which help greatly to that end. Following is a list of these, the more important ones being named first. Wherever a coöperative company succeeds greatly, several of these conditions will be found to exist.

1. *Sound economic need for a coöperative company.*—Such a need exists (1) where present markets give poor service or take too large profits, (2) where the present marketing system is wasteful and expensive, and (3) whenever the farmers by combining can reach better markets with their products or teach themselves to turn out better products. Needless to say, many coöperative companies have been organized where these conditions did not exist. Often an imaginary grievance, hate, spite, or misguided enthusiasm has led farmers to think that a coöperative company was bound to succeed

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[2] Hibbard, B. H., and Hobson, Asher. "Coöperation in Wisconsin." Wis. Exp. Sta. Bull. 282, 1917.

when their sober judgment in the matter told them better afterward. Most of all, the farmers have to look out for the promoters, the men who for a sum of money will convince them that they ought to organize. Many times the promoters are telling them the truth, but more often they are not.

2. *Enough business.*—Small businesses are conducted at high cost in proportion to the products handled. This means that private companies handling more business can undersell them. Farmers thinking about organizing need always to ask themselves how much business they can get right at the start, how much they can expect to take away from private companies, and whether the product they are proposing to sell is increasing or decreasing in importance in the neighborhood.

It is usually important that this business come from a rather small area. If the members of most kinds of coöperative companies are scattered over several townships, they do not have a chance to get acquainted and do not attend the meetings regularly, each of which is undesirable. Most villages and cities draw their trade from a rather closely defined territory around them. People trading in one village are not likely to keep on doing business with a coöperative company somewhere else. In organizing, therefore, it is important to keep within these natural trade areas.

It is also better if the business is one that keeps going throughout the year, like the creamery business. Organizations are likely to die out from season to season if some business is not taken on to keep up the interest. It also costs to have buildings stand idle.

3. *Coöperative spirit.*—Coöperation means working together in order to obtain a larger result than can be obtained individually. When one man holds a ladder while the other climbs, the job is better done than if the two try to climb together. Wherever people are coöperating successfully, they will be found all pulling together, some doing one task which has been assigned them and some doing another, and each having faith that the other will do his part. The most that many of the members have to do is to elect their officers and furnish the business, but this is a most important part and must be done well. The members of a company do not all need to be honorable, upright, peace-loving men, altho these qualities are desirable. Instead, what is needed is that each shall do his part faithfully and let the others do theirs and that all shall have faith that by so doing they will help the common cause. Farmers who have really learned how to coöperate and have come to know the benefits to be gained from coöperation are all very loyal to their companies and to the principle of coöperation, and this loyalty is worth more than all the other things put together.

4. *Interest in the business.*—The people who support a coöperative creamery best are those who get most of their income from milk. Fruit-marketing associations succeed only in sections where fruit is the principal source of income. However, where farming is diversified, as in southern and central Minnesota, farmers may well support a coöperative elevator, a creamery, and a livestock shipping association.

5. *Leadership.*—In nearly every case where farmers coöperate successfully, will be found a group of men belonging to the neighborhood who have worked hard year in and year out to make the enterprise go. Sometimes it is just one man. The reason these men are in the work is that they like it and are greatly interested in coöperation. The rest of the members have faith in these leaders, if they are real leaders and not "cranks"; and those who can not be leaders are content to be followers. The leaders can never be men from the outside.

6. *The personal element removed from the business.*—If there is any chance for the manager to show favoritism, as in grading grain, testing milk, or even figuring out member's checks, then some member is bound to suspect him of being partial to some other member, especially if there is another member of whom he is jealous. Consequently, if coöperation is going to succeed as it should, somebody must study out exact scientific methods of grading farm products and handling the business, with the personal element largely left out.

7. *A simple business.*—Farmers are seldom called upon to handle large, complicated business undertakings, and like other people when they first try they get their affairs into a tangle. But with simple business concerns, like creameries, they succeed splendidly right from the start. Later on, they can safely undertake larger enterprises. The California orange growers have learned how to market oranges in the big central markets, and the Canadian wheat growers have learned how to export wheat. It is well, therefore, for farmers always to be on their guard against new and complicated kinds of business, like meat-packing plants, for example, and ask themselves, "Do we now know enough about the running of this kind of business?"

8. *Proper organization.*—The constitution and by-laws should include the best arrangements anywhere known as to capital, shares, votes, membership, and dividends. Where everything else is favorable, a coöperative company may succeed with a poor organization, but nine times out of ten there are just enough conditions that are bad for coöperation to make a strong organization almost absolutely necessary. No better example can be found of the importance of the right kind of organization. No other one thing is so necessary in coöperation. When coöperation was first tried, the companies failed as rapidly as they were formed. But the "Rochdale Pioneers" discovered a new way of organizing, and since then all coöperative companies

formed on these lines have succeeded much more often than they have failed. Following are some of the arrangements that have worked out best.

9. *Only farmers accepted as members.*—If a company intended strictly for farmers is being formed, only farmers should be accepted as members. This means that all members will be interested in the affairs of the company, and that most of the enemies will be kept out. To carry out this provision, a company must reserve the right in its by-laws to pass on the applications of new members, and also the right to buy the shares of retiring members. While this rule is important, it can be too rigidly enforced. Where retiring farmers are still interested in their farms, or where extra capital is needed badly and retired farmers or friendly city people are willing to buy shares, the farmers *may* do well to take them in.

10. *Limit on the number of shares one member may own.*—This limit is usually five or ten. The state coöperative law places the limit at $1000. This means that about all the patrons of the company will also be members, which is very much to be desired, and also that there will be no large investors more interested in stock dividends and in the safety of the investment than in making the company serve the farmers best. Even tho he has but one vote, a large stockholder in a coöperative company is sure to be very active in his own interests.

11. *One vote per member.*—Regardless of the number of shares a member owns or the amount of business he does with the company, he should be allowed but one vote. This keeps the management of the company in the hands of those who furnish the business, and combined with the rule limiting the number of shares one member may own, keeps the control of the company from ever falling into the hands of a few persons.

However, in lines of coöperation in which many big and little producers are joined in one company, it sometimes works best to divide votes and shares according to the amount of business furnished.

12. *None of the gains of the business paid out as stock dividends.*—With true coöperative organizations the stockholders are paid the prevailing rate of interest for similar risks and no more, and the rest of the profits are distributed according to patronage. It may seem to some to make little difference whether a member receives his share of the profits as a stock dividend or as a patronage dividend. However, it is the business brought to the company, and not the money loaned, which is the real basis of profits, and shares are seldom owned in proportion to the business furnished. The evil of large stock dividends is less if the shares are widely distributed, but still it is an evil and should be avoided. The by-laws should therefore name a limit on the

rate of interest to stockholders. The best way to distribute dividends in most cases is to *pay the farmers* prevailing market prices for their products and afterwards distribute the profits from the transaction as a patronage dividend of a certain per cent, or of so much per bushel or per hundred pounds, as an addition to the market price. Similarly, profits from sales to members are distributed as rebates on their purchases. However, where the farmers can wait for their returns till the company has disposed of their products, as in the case of livestock shipping associations, all the profits can be paid out after every sale. Creameries usually manage their affairs by paying out all the profits along with the cream checks every month.

13. *Enough capital to give the company a good start and to keep it going.*—If the farmers will not provide enough capital to start the company off well without too much coaxing, they are not ready for successful coöperation. Time after time, coöperative companies have failed because the amount of capital needed was miscalculated and the members would not provide any more afterwards, even to save the company from failure. If a plant is to be built, it is always well to figure on a heavier cost than estimated. If the business grows, more capital is soon needed. The best time to raise this money is at the beginning. The farmers are more liberal then. A company usually needs a few years to get on its feet and show its real worth to the members. A call for more money during this period sounds to the farmers like a signal of distress.

Increase in capital as the business grows is often provided by paying out patronage dividends in the form of extra shares of stock, or by using patronage dividends to redeem notes given by the members in payment for shares. Instead, a certain per cent may be deducted from the amounts paid to farmers for their products. The effect of any of these methods is to increase the capital of the company without imposing any noticeable burden on the members.

A company usually should raise enough capital to pay for its plant and equipment, and depend on borrowing, at least after the start, for much of its working capital. Funds for carrying on the business are needed usually for only short periods, and in greatly varying amounts, and it is cheaper to borrow when necessary than to carry a very large surplus on deposit.

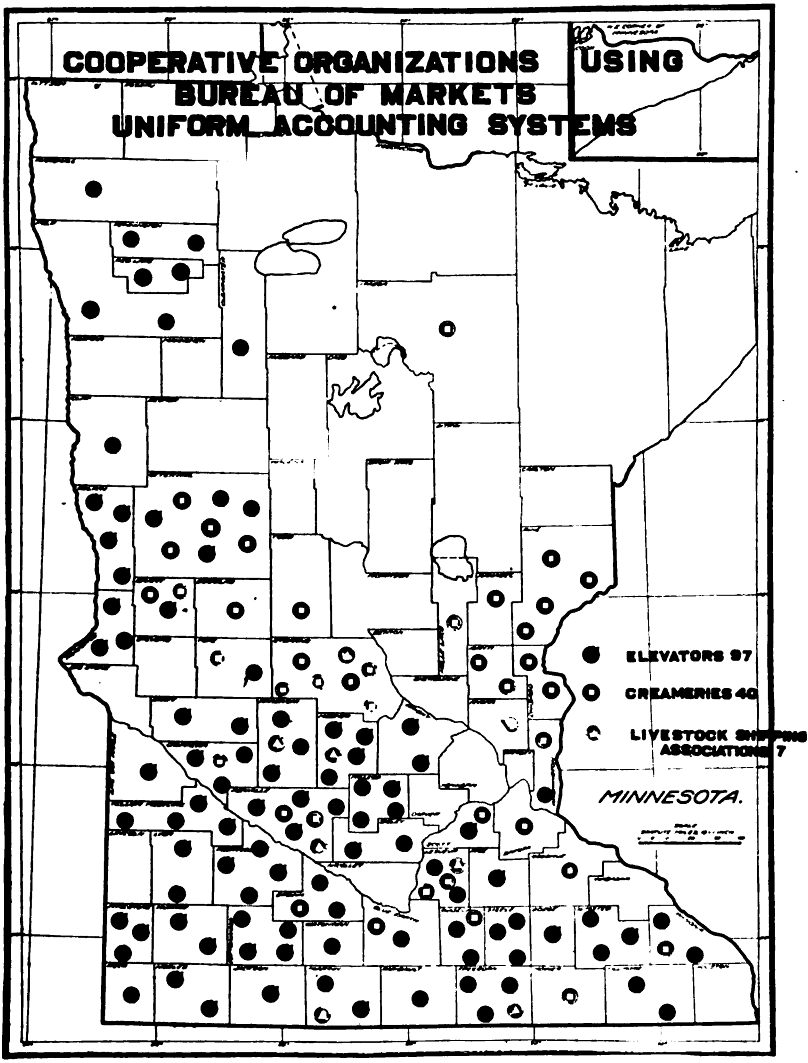
14. *Careful organization of the work.*—This means carefully laying out the work that must be done and giving each officer and each employee his part of it to do. The failure to do this is one of the greatest weaknesses of coöperative companies. Officers and committee-men who must see each other frequently, often live long distances apart. Some who are not officers at all are "taking a hand" in the business. Some of the officers are doing the work of other officers. The result of all this is trouble and confusion.

15. *Efficient management.*—After a machine is set up, someone who understands the business is needed to operate it. All the officers and the members and employees must be kept in their proper places. The president and directors need to know all about the particular business in which the company is engaged. If it is selling grain, they need to know about the grain market. The hired manager absolutely must know, especially if his directors are poorly informed. Farmers are still too likely to think that anybody can market grain or livestock or run a grocery store. Many of them still think that the manager's salary ought to be just a little more than that of a farm hand. The history of many companies in this respect runs about as follows. First, the job is given to the lowest bidder. By the end of the year, the business shows a deficit and everything is in a muddle. The job is then given to some faithful, honest farmer in the community at a somewhat higher salary. Affairs look a little better, perhaps, but it soon becomes evident that successful farming does not always fit one to manage a commercial enterprise. The farmer manager has not kept proper records. The company does not even know where it stands financially. The members begin to get disgusted and call a meeting to talk over the question of selling out to some private concern. If they don't sell out, they are likely at this stage to hire an experienced manager. If they get a good one, the business begins to prosper. All goes well now, until perhaps the members get to thinking that a cheaper manager can handle the business just as well, now that it is on its feet. In this case the whole experience is gone over again. A year or two of bad management will undo all the good results of several prosperous years. Poor management, in one way or another, according to Bradstreet's, caused 80 per cent of the business failures in the United States in 1917. Probably coöperative companies, if the figures were known, would make a similar showing.

16. *Keeping the same officers and managers, whenever they are giving good service.*—"Passing around the honors" is bad for efficient management. Every new officer has to learn the business before he is of much use. Managers and secretaries especially should be kept year after year.

17. *Keeping accurate records and accounts.*—Poor bookkeeping is a large part of poor management. If the books are kept so that the manager does not know where the business stands, and has to guess at things instead of judging from the facts, he is pretty sure to make some bad bargains. He needs to know what it is costing to handle the various parts of his business so as to know what prices to charge, what margins to take, and which departments to discontinue and which to enlarge. If net gain is not properly figured, wrong dividends are declared. Dividends may actually be paid out of capital instead

of earnings. Without good bookkeeping, seldom is anything set aside for reserves against depreciation. Suddenly the company finds itself forced to go out among the members and ask for funds with which to buy equipment. Some of the members quit the company at such times. All these things destroy the confidence of patrons and especially of bankers who are asked to loan money. The labor of keeping books is greatly reduced if suitable desks, filing cases, and adding machines are provided.


COOPERATIVE ORGANIZATIONS USING
BUREAU OF MARKETS
UNIFORM ACCOUNTING SYSTEMS
● ELEVATORS 97
○ CREAMERIES 40
◌ LIVESTOCK SHIPPING ASSOCIATIONS 7
MINNESOTA.

Considerable improvement would undoubtedly result from the general adoption of a uniform accounting system, especially if this were supplemented by extension work and short courses in coöperative bookkeeping conducted by the agricultural colleges. The federal Bureau of Markets has developed uniform systems of accounting specially adapted to the needs of the various types of coöperative organizations. In addition, it is investigating accounting methods, auditing, and business practices, and it maintains a corps of experts to meet, as far as possible, requests for personal assistance. A large number of creameries, elevators, and livestock shipping associations in this state have already availed themselves of this service, and the adoption of uniform systems is making considerable progress. Figure 1 shows the location of these companies.

18. *Careful auditing of accounts by an expert accountant.*—In order to discover if they have been properly kept, uncover any possible frauds, and show the true profit and loss and the true financial condition of the business, the books should be carefully audited by an expert. This audit is something quite different from the so-called audit made every two or three months by a committee of the stockholders and directors. The cost of auditing can be greatly lessened if coöperative companies will organize auditing associations, such as are now in operation in Europe and in certain states in this country.

19. *Community of feeling.*—Coöperation works better if the people in the community have much in common, if they belong to the same race, have the same religion, and are all about equally well-to-do. Coöperation is also easier where only a few of the farmers are shifting tenants. Altho all of these things help, they are not necessary. A large number of mixed communities of farmers have already learned to coöperate, and many more will do so.

20. *Friendly assistance of the business men and people in city or village.*—All right-thinking city people ought to favor coöperation, but in most places a few short-sighted business men and others will spread false reports about coöperative enterprises and fight them in every way they can. This is unfortunate and may cause the ruin of the company. All that the farmers can do in such cases is to try to coöperate in spite of them.

21. *Federation of coöperative enterprises as soon as they are ready for it.*—A federation can handle the marketing problems for all the separate companies, can standardize products, advertise, buy supplies, audit the books, fight for the companies in the legislature and in the courts, and more than all else, keep the separate companies from crowding into each other's territory. In this country, the citrous fruit growers of California are so federated; also the cheese producers of Sheboygan county, Wisconsin. In Canada, the grain growers are federated.

22. *An organization adapted to local conditions.*—Probably every one of the foregoing recommendations is unsuited to some local circumstances. Farmers therefore need to use common sense and good judgment in applying them. However, it will always be safe for them to assume these recommendations to be suited to their conditions till they find good reasons to the contrary.

Many of these factors will be discussed again in connection with special kinds of coöperation. Also some new factors will be introduced.

COÖPERATIVE CREAMERIES[3]

The number of coöperative creameries in Minnesota increased from 622 to 643 between 1914 and 1917, and the percentage of coöperative creameries from 73.2 to 76.4. Table II shows that this is a higher percentage that that of any previous year except 1911, when it was 77.2. The number of proprietary creameries decreased from 210 in 1912 to 159 in 1917. The centralizer creameries, however, have increased from 30 to 39 since 1911. Percentage of butter made, however, is a fairer measure than numbers of the importance of these three types of creameries. Table VI shows that the 39 centralizers made 25.5 per cent of the Minnesota creamery butter in 1914, and 27.7 per cent in 1917. The proprietary creameries made only 13.1 per cent of the butter in 1914, and only 10.6 per cent in 1917. The coöperative creameries have gained only a fraction of one per cent during this period. Part of the butter made by the centralizers is made from cream shipped in from outside the state.

TABLE II

COOPERATIVE MOVEMENT AMONG MINNESOTA CREAMERIES, 1910-1917*

Year	Number of creameries			Percentage of number cooperative	Amount of butter made			Percentage made by coöperative creameries
	Coöperative	Proprietary	Centralizers		Coöperative	Proprietary	Centralizers‡	
1910	560	190	13	74.8	Lbs.	Lbs.	Lbs.	Lbs.
1911	606	178	30	77.2	†	†	†	†
1912	621	210	33	71.9	†	†	†	†
1913	614	204	34	72.2	†	†	†	†
1914	622	189	39	73.2	74,079,146	15,764,091	30,856,368	61.4
1915	655	174	35	75.7	76,767,006	17,615,802	31,767,857	60.9
1916	646	165	39	76.3	79,815,936	16,275,411	36,298,825	60.5
1917	643	159	39	76.4	75,325,732	12,919,109	33,860,054	61.7

* These figures are taken from the 1917 reports of the State Dairy and Food Commission.

† Figures not available.

‡ Some of the butter made by Minnesota centralizers is made from cream shipped in from outside the state.

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[3] All data given in tables II to VI were obtained from the records of the State Dairy and Food Department. Thanks are hereby extended to the Dairy and Food Department, the Railroad and Warehouse Commission, and all other public agencies that allowed the use of their records.

Tables III, IV, and V make further comparison of the three types of creameries in 1917. The coöperative creameries averaged 18 more patrons, 136 more cows, and 36 per cent more butter per creamery than the proprietary creameries. One reason for the larger amount of butter is the 14 per cent more butterfat per cow. Because they made more butter, the coöperative creameries made it cheaper, six-tenths of a cent less per pound of butterfat, which is the same as a half cent per pound of butter. Besides, they received 2.1 cents more per pound for their butter. As a result of these advantages, they were able to pay their patrons 2.6 cents more per pound for butterfat and still have left $1,040 per creamery to distribute as dividends, reserve fund, and surplus. The centralizers paid patrons less per pound of butterfat and made their butter at a lower cost than the proprietary creameries. In figuring these prices, all cream transportation charges were subtracted before naming the amounts paid to the patrons. The net profits reported for centralizer creameries are probably not all profits, but include some of the unusual expenses not borne by local creameries.

TABLE III

SUMMARY OF BUSINESS OF COOPERATIVE CREAMERIES AND COMPARISON WITH PROPRIETARY AND CENTRALIZER CREAMERIES, 1917*

		Kind of creameries		
	Coöperative	Proprietary	Centralizer	Percentage of total coöperative
Number of patrons	71,414	14,066	29,558	62
Number of cows	548,663	107,866	217,901	62
Milk received, lbs.	187,592,790	23,265,833	4,155,159	87
Cream received, lbs.	215,573,042	32,725,452	92,089,042	63
Butterfat, lbs.	61,577,684	10,595,401	27,499,042	62
Butter made, lbs.	75,325,732	12,919,109	33,360,054	61
Amount paid patrons	$28,001,194	$4,549,872	$11,624,705	63
Running expenses	$2,130,079	$433,143	$889,320	61
Amount received for butter	$30,800,724	$5,160,049	$13,212,141	62
Gross profits	$2,799,530	$610,177	$1,587,436	56
Net profits†	$669,451	$177,054	$698,116	43

* These figures are for 638 coöperative creameries, 149 proprietary creameries, and 39 centralizers.

† Only running expenses deducted.

TABLE IV

AVERAGES PER CREAMERY FOR THE THREE CLASSES OF CREAMERIES, 1917

	Coöperative	Proprietary	Centralizer
Number of patrons	112	94	758
Number of cows	860	724	5,587
Milk received, lbs	294,032	156,146	106,542
Cream received, lbs.	337,888	219,634	2,361,257
Butterfat, lbs	96,516	71,110	705,103
Butter made, lbs	118,065	86,705	855,414
Amount paid patrons	$43,889	$30,536	$298,069
Running expenses	$3,338	$2,907	$22,803
Amount received for butter	$48,276	$34,631	$338,774
Gross profits	$4,387	$4,095	$40,705
Net profits	$1,049	$1,188	$17,902

Table VI compares the three types of creameries for 1914 and 1917. In prices received for butter and prices paid for butterfat, the cooperative creameries have gained on their competitors. Besides, their expenses have increased less than those of the proprietary creameries. Coöperative creameries have increased their net profits only slightly; the other two types of creameries have increased them very noticeably.

TABLE V

COMPARISON OF SPECIFIC FACTORS FOR THE THREE KINDS OF CREAMERIES, 1917

Factors	Coöperative	Proprietary	Centralizer*
Cows per patron	7.7	7.7	7.4
Butterfat per cow during the year, lbs	112.0	98.2	.....
	Cents	Cents	Cents
Price received per pound for butter	40.9	38.85	39.6
Expenses per pound of butter	2.8	3.3	2.7
Price paid patrons per pound for butterfat	45.5	42.9	42.3
Price received per pound for butterfat†	50.0	48.7	48.0
Gross profits per pound of butterfat	4.5	5.8	5.7
Expenses per pound of butterfat	3.5	4.1	3.2
Net profit per pound of butterfat	1.1	1.7	2.5
Per cent gross profit on price paid for butterfat	10.1	13.4	13.6
Per cent net profit on price paid for butterfat	2.4	3.8	6.0

* The figures in this table are derived from the figures actually reported by the creameries. The figures reported by centralizers do not seem to be entirely consistent.

† Part of the factors are figured on the basis of pounds of butterfat instead of pounds of butter. Some creameries dispose of considerable butterfat as ice cream.

In comparing prices paid by centralizers, it must be borne in mind that the cream which they buy is often of inferior quality, and that much of it comes from sections not producing enough milk to support a local creamery, some of it from outside the state. The coöperative creameries are able to secure a higher quality of raw material, turn out a better product, and obtain prices which amply repay them for all extra care and effort.

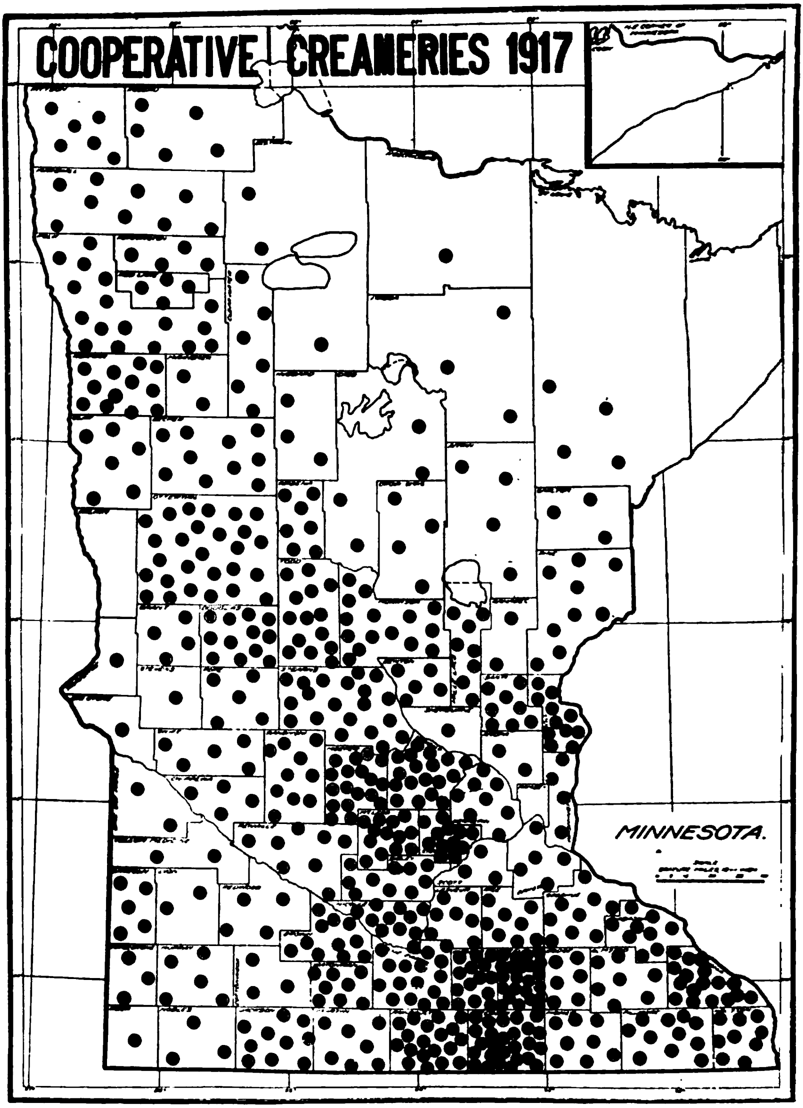
TABLE VI

COMPARISON OF SPECIFIED EFFICIENCY FACTORS FOR THE THREE KINDS OF CREAMERIES, 1917 AND 1914

Factors	Coöperative		Proprietary		Centralizer	
	1917	1914	1917	1914	1917	1914
Percentage of all creameries	76.4	73.0	18.9	22.0	4.7	5.0
Percentage of all butter made	61.7	61.4	10.6	13.1	27.7	25.5
	Cents	Cents	Cents	Cents	Cents	Cents
Price paid patrons per pound for butterfat	45.5	30.4	42.9	29.0	42.3	29.0
Price received per pound of butterfat	50.0	33.7	48.7	33.0	48.0	33.7
Expense per pound of butterfat	3.5	2.8	4.1	3.0	3.2	3.0
Net profit per pound of butterfat	1.0	0.7	1.7	1.1	2.5	1.3
Expense per pound of butter	2.8	2.5	3.3	2.4	2.7	2.5
Per cent of gross profits on price paid for butterfat	10.1	11.4	13.4	13.4	13.6	15.0
Per cent of net profit on price paid for butterfat	2.4	2.4	3.8	3.9	6.0	4.7

Table VII shows the results of a special inquiry as to the way in which the coöperative creameries disposed of their surpluses. Since more than three fifths of the creameries responded to the inquiry, the result should be reasonably representative. More than two fifths, or 43 per cent, of the creameries made no profits at all; that is, they paid out all of their receipts above expenses each month to the patrons.

Apparently 3 per cent of them miscalculated a little toward the end of the year and contracted small losses. The rest were on the profit side of the account at the end of the year with an average of $798.



Coöperative creameries generally include stock dividends in expenses, but there were some that in 1917 undoubtedly included them in profits. The average profits of $437 for the 393 creameries reporting is therefore somewhat higher than it should be. These profits, plus the amount paid against debt, should really be added to the amount paid patrons for butterfat, because they are actual additions to the wealth of the patrons. They represent six tenths of a cent per pound of butterfat.

TABLE VII

DISPOSITION OF SURPLUS OF COOPERATIVE CREAMERIES, 1917

Disposition of surplus	Number reporting	Percentage of creameries*	Average amount reported
Profit and loss	393	100	$437
Profits†	213	54	798
Losses	12	3	194
Neither profits nor losses	168	43	....
Surplus not distributed	94	24	....
Stock dividend only	138	35	276
Patronage dividend only	10	3	742
Both dividends	12	3	1,416
Sinking fund or reserves‡	165	42	831
Paying off debt	105	27	978

* Percentage of those making report on profits and losses.

† Many creameries included dividends in profits.

‡ The creameries reported under this heading many things besides reserves, for example, undivided surplus, funds used to pay current expenses, etc.

Only 35 per cent of the coöperative creameries paid stock dividends only, 3 per cent paid patronage dividends only, and 3 per cent both dividends. Table VIII shows the dividend rates paid by 150 coöperative creameries. More than two fifths of them pay 6 per cent or less, and more than three fourths of them pay 8 per cent or less. Only five per cent pay more than 10 per cent. The average amount of stock dividend paid was $276. Of the 22 companies reporting patronage dividends, 14 paid on the percentage basis, usually 6 per cent, and 8 paid so much per pound of butterfat, usually 1 cent.

TABLE VIII

DIVIDENDS PAID ON CAPITAL STOCK BY 150 COOPERATIVE CREAMERIES, 1917

Per cent of dividend	Number paying	Per cent of dividend	Number paying
½	1	7½	1
1	2	8	34
1¼	1	10	28
2	1	11	1
4	4	12	3
5	14	15	2
6	40	20	1
7	16	25	1

Obviously the farmers' creameries of Minnesota are thoroly coöperative. Even tho only a few patronage dividends are paid, the patrons get the full benefit of coöperation. The common practice of paying out all the net receipts each month is thoroly coöperative. The only question to be raised concerning it is whether it means good accounting under all circumstances, whether it provides properly for meeting annual payments like taxes and interest, and for distributing large expenditures over the year. A majority of the companies seem to have some sort of a sinking fund, but the companies paying out all their net receipts each month are usually the ones that have no sinking fund.

An earlier inquiry showed that all but 3.5 per cent of the companies have adopted the one-man one-vote principle, and that 65 per cent of them limit the number of shares which one person may own, and that the limit is one share in a third of the companies, and not more than ten shares in 83 per cent of the companies.

Bulletin 166, which will be sent to anyone upon request, contains many other details as to organization and management of coöperative creameries; also a sample constitution and by-laws and full details as to the method of organizing.

FACTORS OF SUCCESS WITH COÖPERATIVE CREAMERIES

There can be no doubt as to the success of coöperative creameries in Minnesota. No other state has so many or so large a percentage of coöperative creameries as Minnesota. In the great dairy state of Wisconsin, according to Bulletin 282, already referred to, only 45.5 per cent of the creameries are coöperative. The average age of 337 creameries reporting on this question in 1917 was 13.4 years. More than one third of these were organized before 1900. Nevertheless, not all coöperative creameries succeed, and some companies even fail after succeeding for a time. The names of 38 companies have been reported to this division as having failed in the last 3 years. The reasons given were: Not enough business, 17; competition of centralizers, 6; competition of cheese factories, 1; lack of coöperation, 3; new creameries better located, 2; mismanagement, 2; fire, 1. Some of these did not really fail, but merely combined with other creameries. Of interest also is the fact that 99 out of 405 companies reported having reorganized once, and 2 reported having reorganized twice. Following are some of the matters of special importance to the success of coöperative creameries.

1. *Enough business.*—As a matter of fact, lack of patronage was the cause of nearly all the failures above reported. A creamery may lack patrons because it is located in a neighborhood where there are few farms or few cows, but usually it is because some competing firm is taking away part of the patrons. The important thing, therefore, is to locate the creamery and organize and manage it so that it can compete to advantage. Farmers considering organizing new creameries must not count too much on taking patrons away from competitors. The old company will fight the new one, and in doing so offer as many new inducements to patrons as it can afford. A few members who prove disloyal to the new company may be enough to put it at a disadvantage. Above all else, coöperative companies must avoid cut-throat competition with each other. Each company should stay content in its own natural territory. Every coöperative creamery that fails hurts the cause of coöperation more than several successful companies help it. The reason that size of business is important with

creameries is that it costs more per pound to make a small amount of butter than a large amount, because the plant, the equipment, and the buttermaker are not being put to full use. Even tho only a little butter is made, many of the expenses go on just the same.

2. *Quality of butter.*—A difference of a few points in the score of butter on the New York market may result in a difference of from 6 to 8 cents in prices. The place to begin improving the product is on the farm. Creamery operators have already done much to get their patrons to take better care of their cream, but there is much more to be done even in Minnesota. Where cream stations are not too near, sometimes a creamery can deduct from 1 to 3 cents per pound of fat for all cream grading lower than No. 1.

3. *Uniform product.*—A medium quality of butter which is uniformly good week after week often finds a better market than butter which is very good just most of the time. Buyers want butter they can sell to their customers regularly without offense. Creameries making a uniformly high grade of butter will find it well to get a license from the State Dairy and Food Department and market it under the Minnesota brand.

4. *A good buttermaker.*—The creamery operator is so often manager as well as buttermaker that he must be a combination of expert buttermaker, good bookkeeper, and good business man. He is more responsible than anybody else for a high and uniform quality of butter, for keeping costs low, and for keeping the patrons pleased and contented. He needs tact about as much as skill and knowledge. Even if the creamery has a separate manager, the buttermaker carries a large part of the responsibility.

CHEESE FACTORIES

The cheese factories of Minnesota will soon be as largely coöperative as the creameries. Already 68 per cent of the American cheese factories and 62 per cent of all cheese factories are in that class. Only one of the 6 brick-cheese factories is coöperative. Table IX shows the changes in the number of the three types of cheese factories since 1911.

TABLE IX

NUMBER OF COOPERATIVE, INDEPENDENT, AND CENTRALIZER CHEESE FACTORIES, 1911-1917

Year	Coöperative	Independent	Centralizer	Total	Percentage coöperative
1911	32	33	4	69	46
1912	30	29	4	63	47
1913	38	28	4	70	54
1914	36	31	4	71	51
1915	39	25	3	67	58
1916	49	31	3	83	59
1917	52	28	3	83	62

Table X analyses the business of 38 coöperative and 18 proprietary factories. As with creameries, the coöperative companies did a larger business, sold their product for a better price, and paid patrons more for their milk. Out of every $100 of gross receipts, they paid back to the patron $4.80 more than did the proprietary factories. Their manufacturing expenses seem to have been somewhat higher than those of the other factories. Apparently the coöperative cheese factories do business largely on a non-profit basis.

TABLE X

Analysis of Business of Coöperative and Proprietary Cheese Factories, 1917

	Coöperative	Proprietary
Milk delivered per factory, lbs	1,278,954	864,802
Cheese made per factory, lbs	122,885	86,961
Amount paid patrons per factory	$25,987	$16,897
Gross receipts per factory	$28,905	$19,883
Gross profits per factory	$2,918	$2,986
Running expenses per factory	$2,697	$1,768
Net profits per factory	$221	$1,218
Average yield, per cent	9.60	10.05
	Cents	Cents
Paid patrons per pound of cheese	21.2	19.5
Received per pound of cheese	23.6	22.9
Expenses per pound of cheese	0.219	0.203
Net profit per pound of cheese	0.2	1.4
Percentage of gross receipts paid patrons	89.8	85.0

FARMERS' ELEVATORS

This division has the names of 380 farmers' elevators on its mailing list. The Railroad and Warehouse Commission received reports of the amount of grain of the 1917 crop handled by 360 farmers' elevators. In addition, perhaps a fifth of the 50 to 75 elevators that failed to report the amount of grain handled were farmers' elevators.

However, not all of these are strictly coöperative. The farmers own and control a majority of the stock in all of them, but in some cases the stock is in relatively few hands and rather high stock dividends are paid. However, the 251 reporting to this division, whose business is summarized in Table XI, all have their shares rather widely distributed. The same is known to be true of a large majority of the remainder. The number reporting each year to the Railroad and Warehouse Commission is probably not far from the number of essentially coöperative elevators. The reports from these companies are summarized in Table XII.

The number of farmers' elevators reporting has increased from 296 to 360 in four years. This is a net increase of 16 per year. In addition, several companies not strictly farmers' companies have been transferred out of that class each year. Trade journals reported the names of 21 new farmers' elevators between June 1, 1916, and June 1, 1917, and the names of 28 more by December 1, 1918. This is at the rate of 20 per year. If this is a true average, the difference is due to the several companies that fail each year. The increase in percentage of elevators from 20.8 to 23.0 per cent is more significant than the increase in number. Some of the figures as to the number of mills and independent elevators are irregular because not all have reported each year and because of changes in classification.

TABLE XI

SUMMARY OF BUSINESS OF FARMERS' ELEVATORS, 1917 and 1918

	Number reporting amounts	Total for companies reporting amounts	Averages for companies reporting
Gross receipts	251	$48,661,550	$208,251
For grain and flour	232	43,837,542	188,955
For supplies	250	4,824,008	19,296
Operating expenses	228	1,135,259	4,980
Profit and loss	241	949,658	3,941
Stock dividends	149*	192,827	1,294
Patronage dividends	49†	193,038	3,939
Sales of grain and flax	232	$43,837,542	$188,955
Sales of coal	191	1,570,166	8,221
Sales of flour	104	572,806	5,527
Sales of feed	106	475,157	4,483
Sales of flour and feed‡	36	476,185	13,225
Sales of other supplies	144	1,729,694	12,012
Bushels grain and flax	234	30,781,549	131,549
Tons of coal	162	178,595	1,102
Barrels of flour	78	33,611	431
Tons of feed	88	8,133	92
Member patrons	166	18,784	113
Patrons not members	118	10,185	76
Farmer members	168	18,149	109
Members not farmers	146	3,206	22

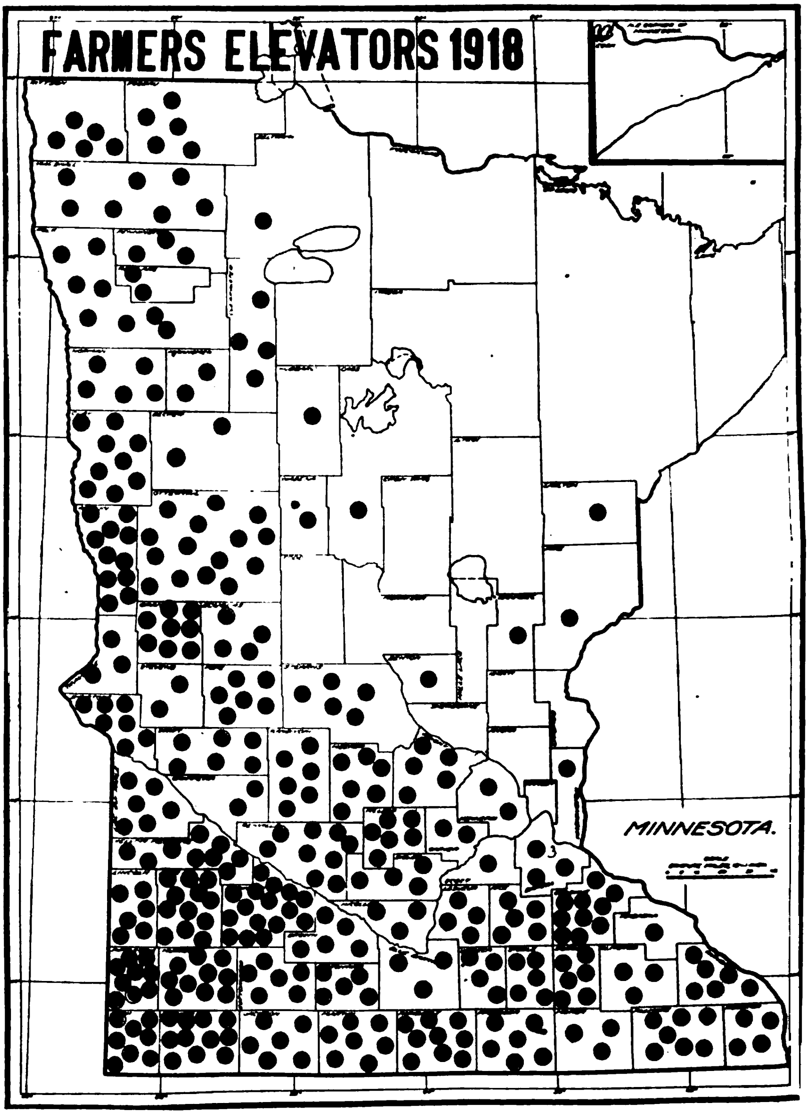
* Fifteen other companies reported stock dividends but did not give amounts paid.
† Nine other companies reported patronage dividends but did not give amounts paid.
‡ Not reported separately.

TABLE XII

COMPARISON OF BUSINESS OF FARMERS' AND OTHER ELEVATORS, 1914 to 1917

Kind of elevator	Number of elevators	Percentage of all elevators	Grain shipped	Percentage of all grain shipped	Average per elevator
Farmers'			Bushels		Bushels
1914-15	296	20.8	43,489,482	39.0	146,890
1915-16	299	19.0	37,374,690	35.5	124,998
1916-17	331	21.8	33,879,501	38.9	102,325
1917-18	360	23.0	45,205,695	40.1	125,571
Line					
1914-15	625	43.8	....	....	....
1915-16	630	40.1	34,670,002	32.9	55,032
1916-17	613	40.2	22,579,948	25.8	36,835
1917-18	613	39.2	31,659,280	27.9	51,630
Independent					
1914-15	302	21.0	....	....	....
1915-16	407	25.9	24,434,435	23.2	60,035
1916-17	357	23.4	16,371,188	18.8	45,857
1917-18	347	22.2	20,863,772	18.5	60,126
Mill-elevators					
1914-15	205	14.4	....	....	....
1915-16	234	15.0	8,712,960	8.3	37,234
1916-17	222	14.6	14,407,753	16.5	64,899
1917-18	245	15.6	15,131,953	13.5	61,763
All elevators					
1914-15	1,428	100.0	111,667,146	100.0	78,198
1915-16	1,570	100.0	105,192,087	100.0	67,001
1916-17	1,523	100.0	87,238,390	100.0	57,214
1917-18	1,565	100.0	112,860,700	100.0	72,115

The new companies are mostly in southeastern and northern Minnesota. The Red River Valley has gained 20 farmers' elevators since 1913, and the southeastern counties about 40. The counties with fewer coöperative elevators now than in 1913 are mostly in west central Minnesota. Figure 3 shows that the grain-growing regions of the state, except for a few counties, are already well supplied with farmers' elevators.



The 360 farmers' elevators, altho only 23 per cent of the whole number of elevators in the state, handled 40.1 per cent of all the grain that was shipped out of local elevators during 1917-18. This is because the farmers' elevators each handle more than twice as much grain as either the line or independent companies. In 1914-15, which seems to have been an unusual year, the coöperative elevators handled 39 per cent of the grain. In 1915-16 they handled 35.5 per cent of it, and in 1917, 40.1 per cent. The increase has been mostly at the expense of the line elevators. The mill elevators have handled an unusual amount of grain the last two years.

The 112,860,700 bushels of grain shipped by country elevators in in 1917-18 was 35.8 per cent of the 315,724,000 bushels produced in the state in 1917, according to the reports of the Bureau of Crop Estimates. Of the 1913 crop, 43 per cent passed through country elevators. The 1917 crop was divided as follows:

	Bushels
Wheat	36,675,877
Flax	2,133,228
Oats	42,905,183
Corn	7,201,133
Rye	5,978,945
Barley	17,966,334
Total	112,860,700

Table XI summarizes the reports of the companies making returns to this division. The gross receipts of the 251 companies averaged $208,251. Of this amount, $19,296 was obtained from sales of supplies. Gross receipts in 1913 were $89,000 per company, $7,400 of this coming from sales of supplies. Rising grain prices account for the increase in receipts from grain. Minnesota farm grains increased 96 per cent in price between 1914 and 1918. The increase in receipts from supplies is largely due to a general growth of business in this field. Table XIII shows that 76 per cent of the companies handled coal in 1917-18 as compared with 63 per cent in 1913-14. Furthermore, each company handled 200 tons more coal. Flour and feed show the same increase. Miscellaneous business also increased greatly, altho no doubt more of this could have been separately reported as twine, salt, and seeds.

TABLE XIII

NUMBER AND PERCENTAGE OF FARMERS' ELEVATORS HANDLING VARIOUS COMMODITIES, 1916 and 1917

Commodity	Number reporting sales		Percentage of companies which sell these commodities		
	1914-15	1916-17*	1912-13	1914-15	1916-17
Grain and flax	173	232	100	100	100
Coal	112	191	63	65	76
Flour	71	140	40	41	56
Feed	88	142	41	51	57
Salt	30	35	16	17	14
Seeds	17	18	18	10	7
Twine	51	52	35	28	20
Miscellaneous	49	135	...	29	54

* Includes companies reporting sales of given commodities but not reporting amounts sold.

Other commodities handled were machinery, lumber, wood, cement, tile, fencing, oil, and tires. Five companies also shipped livestock and four shipped potatoes.

The 234 companies reporting grain in bushels averaged 131,549 bushels as compared with 125,571 bushels shipped by 360 companies reporting to the Railroad and Warehouse Commission. Most of this difference is due to local sales of grain.

If the gross receipts of the 360 companies are estimated on the basis of the companies reporting, the results are as follows:

Grain and flax	$66,000,000
Coal	2,250,000
Flour	1,165,000
Feed	965,000
Other supplies	2,490,000
Total	$72,870,000

Table XIV shows that 94 per cent of the companies made profits averaging $4,254, and that 5 per cent had losses averaging $1,236. The average profit and loss of the 241 companies reporting this account was $3,941. This is 1.9 per cent of the gross receipts. In 1914-15, the profits were 2.7 per cent of the gross receipts. Most of the difference is because of the rise in prices. A margin of two cents a bushel is a smaller percentage of $2 a bushel than of $1 a bushel. Some of the difference is no doubt merely a matter of accounting. Most of the farmers' elevators included both stock and patronage dividends in the profits, but an increasing number of them figure at least stock dividends as expenses. The rest of the difference seems to be due to insufficient margins taken on some kinds of grain. The market was so irregular that it was hard to find a safe price to offer. Proof of this is the fact that 61 of the companies making profits did not have enough to warrant paying dividends as compared with 36 in 1915.

TABLE XIV
DISPOSITION OF SURPLUS OF FARMER'S ELEVATORS, 1917 and 1918

Items reported by elevators	Number reporting	Percentage of elevators reporting	Average amount reported
Profit and loss	241	100	$3,941
Profits	227	94	4,254
Losses	13	5	1,236
Neither profits nor losses	1	....	....
Surplus not distributed	35	15	....
Stock dividend only	109	45	1,472
Patronage dividend only	3	1	10,599
Both dividends	55	23	4,358
Sinking fund or reserve	102	42	[•]

[•] The companies reporting did not always distinguish between reserves and undivided surpluses.

Small profits do not mean that coöperative elevators are not prosperous, but only that they are paying high prices for grain or grading high. Most companies, coöperative, line, and independent alike, now set their prices strictly according to the daily market quotations, but they still have a large leeway in grading and dockage. Figures collected several years ago showed that at competitive points, farmers' elevators, like all others, grade higher than they do elsewhere. The result is lower profits and lower dividends, but larger grain checks when the grain is delivered. The disadvantage of this is that the company has not enough of a margin for safety, and may find itself with a deficit at the end of the year.

TABLE XV

DIVIDEND RATES ON CAPITAL STOCK OF FARMERS' ELEVATORS IN MINNESOTA, 1917 and 1918

Rate of dividend	Number of elevators reporting
Per cent	
None*	75
2	1
4	2
6	12
7	10
8	36
9	1
10	42
12	2
15	8
20	15
21	2
22	7
25	1
30	5
40	10
50	1
54	4
100	1

* Of the 75 companies reporting no dividends, 13 made no profits.

It is better to pay high prices for grain, however, than to collect large surpluses and pay them out as dividends to stockholders. Table XV shows that 45 per cent of the companies paid stock dividends only, and only 23 per cent of them paid both stock and patronage dividends. Three companies paid patronage dividends only. Of the companies reporting 1914-15 business, 49.6 per cent paid stock dividends only and 29.1 per cent patronage dividends in addition. The companies had larger profits to divide that year. Table XVI shows for the two years the percentage of dividend-paying companies which paid certain rates. More of the companies paid rates below 8 and 10 per cent in 1917-18, and fewer of them paid the higher dividends. Lower profits, however, may explain all the apparent improvement. It is to be hoped that soon all the farmers' elevators will place a limit of 8 per cent or less on stock dividends. Ten per cent is certainly too high in most cases. Farmers who demand higher rates either do not understand the principles of coöperation, or else they are so pleased with the profits they are now making on their neighbors' business that they cannot bear to forego them even for the sake of fair play. The provision of the federal income tax law exempting patronage dividends from taxation is proving a great benefit in this particular, and many companies have recently amended their constitutions so as to limit stock dividends.

TABLE XVI
DIVIDEND RATES ON CAPITAL STOCK

Rate of dividend	Percentage of all companies paying stock dividends	
	1914–15	1917–18
Per cent		
1 to 8	29.7	38.1
9 to 10	33.3	26.9
11 to 19	5.5	6.3
20 to 49	23.4	25.0
50 and more	8.1	3.7
More than 8	70.3	61.9
More than 10	37.0	35.0
Total	100.0	100.0

Operating expenses in 1917-18 were 2.4 per cent of gross receipts, as compared with 2.6 per cent in 1914-15. The higher prices received for grain explain this. If figures were available, they would no doubt show higher expenses per bushel.

Table XI shows an average of 113 member patrons, and 76 patrons not members, or a total of 189 patrons per company. This means that about sixty-eight thousand farmers are being served by coöperative elevators as compared with 58,000 in 1914. This is two fifths of the farmers in the state. Table XII shows that these elevators are also handling two fifths of the grain. In addition, the companies have about seven thousand members who are not farmers, and a large number of city customers for their supplies.

The farmers' elevators of Minnesota actually distributed about $630,000 in dividends in 1917-18, and in addition accumulated $700,000 as reserve funds and undivided surplus. This is but a small part, however, of the gains from this form of coöperation. The gains from the higher prices they have received for grain, and from the resulting higher prices paid by competing companies, can not be estimated. The coöperative movement is making a healthy growth in this field. Nothing short of a decline in grain farming can check its progress. When the companies all become truly coöperative, the movement will spread even more rapidly.

Bulletins 152 and 164, prepared by this division, give details as to the organization and management of farmers' elevators. Bulletin 152 tells how to organize a company and how to reorganize under the coöperative law, and gives a sample form of constitution and by-laws. Bulletin 164 gives a form for an annual report to the stockholders. These bulletins will be sent to anyone upon request.

ESSENTIALS TO SUCCESS OF COÖPERATIVE ELEVATORS

Following are a few points of special importance to the success of farmers' elevators:

1. *Enough business.*—An elevator has so much money tied up in buildings and equipment that it must do a big business in order to do it cheaply. Bulletin 152 contains the following figures:

Number of bushels handled	Average cost of handling Cents per bushel
50,000-100,000	2.5
100,000-150,000	1.9
150,000-200,000	1.5
200,000-300,000	1.3
300,000-400,000	1.15

It is largely because the farmers' elevators average twice as much business as their competitors that they are so successful. A community can not afford to have several elevators handling its grain. The farmers need to get behind one elevator and make it grow till it absorbs the whole business. Of course they will never be entirely safe under such circumstances unless it is their own elevator. On the other hand, farmers need to be cautious about starting new coöperative elevators unless they can get enough business. Ordinarily 100,000 bushels is about what a new company should try to obtain, unless it happens that the independent or line companies competing are still smaller, or that these companies are giving poor service.

2. *Good managers.*—Farmers' elevators have frequently taken their managers from the line houses they have supplanted. These men are often the best available, but they are not always satisfactory. They have been accustomed so long to looking after the interests of the elevator company that it takes them a long while to realize that a coöperative elevator is managed in the interest of the farmers. Then, too, they now have to buy, sell, hedge, select markets, and keep books, and do all these things largely according to their own judgment, when formerly most of this was done for them at the central office. However, in the twenty years that farmers have been running their own elevators, many men have been trained, and some of their wisdom has been passed on to the present generation of managers.

3. *No speculating.*—Every year several companies get into trouble because their managers or their officers try to "play" the market, either on their own account or for the company. Some way ought to be provided of supervising farmers' elevators to prevent such practices, just as banks are supervised to prevent wild investments. Experience seems to show that the companies ought to provide this themselves by combining into a federation.

4. *A year-round business.*—Farmers' elevators usually take on farmers' supplies as a sideline to keep up the interest of the farmers from season to season, and to reduce expenses by keeping equipment

in use the year round. Bulletin 164 shows that up to the point where such extra business can be done without hiring extra help, the saving is very great, and that even beyond that point the saving is noticeable under efficient management. The figures already presented show that the companies are making progress in this direction.

5. *Saving by-products.*—Country elevators are just beginning to take advantage of this chance to reduce costs. The wild oats and mustard seed screened from grain during the last two years have sold at exceedingly high prices. Besides, the saving in freight from shipping only clean grain is an important item.

6. *Proper organization.*—The facts seem to be that only one third of the farmers' elevators, in their by-laws, limit stock dividends and provide for patronage dividends; that of this one third, only 56 per cent limit it to 8 per cent or less, and 83 per cent to 10 per cent or less; that 20 per cent of them either set no limit to the number of shares one person may own or else set a very high limit; and that 5 per cent of them do not even limit members to one vote. The reason for this is that most of the companies were formed before the coöperative law was passed, and they do not care to change as long as they prosper as they do. Nevertheless, each of these provisions stands for something vital in coöperation, and sooner or later, one after another, each of these companies will find it necessary or advisable to change.

COÖPERATIVE POTATO AND PRODUCE SHIPPING COMPANIES

The mailing list of this division contains the names of 22 potato warehouse associations, potato growers' associations, and coöperative produce companies. Eleven of these have responded to inquiries, and reports from other sources indicate that at least four more were in operation in 1917. No doubt some of the others are still in existence, tho perhaps not operating at present. In Table I the number has been placed at 15.

The reports received indicate very little uniformity in methods of doing business. Six of them handle potatoes only. The other 5 combine potato shipping with some other kind of coöperation, 2 of them with a feed and elevator business, and 2 with livestock shipping, one one of these also including eggs, poultry, hides, and wool. Still another combines potatoes with fruit and berries and a coöperative store. Seven of the 11 companies handle the business on the same basis as the coöperative elevators handle grain, paying cash on delivery and the rest in dividends. Of these 7 companies, 6 limit the stock dividend, 5 of them to 6 per cent, and 1 to 10 per cent. These six all provide for a patronage dividend. Two of the remaining 4 companies simply grade, store, and load potatoes for farmers at a flat rate per bushel, the farmers making their own sales. Another company simply buys for a commission firm at a flat rate per hundred pounds. The only other company reporting combines three methods, paying cash on delivery, handling and storing for the farmers at 3 cents per bushel, and in addition marketing the potatoes at 5 cents per bushel.

The eleven companies handled a total of 192,000 bushels of potatoes, and these sold for $157,000. However, since one fourth of these were stored or handled on commission, the actual gross receipts from potatoes were only $121,000. This means 17,400 bushels per company, and average gross receipts of $11,010. However, the business from other sources averaged $24,770 per company. This makes a total of $35,710 per company. It would thus seem that potato shipping was almost a side line. Undoubtedly potatoes alone have not furnished enough business in some localities to maintain large prosperous companies. However, the largest 5 of the companies handling only potatoes averaged 27,000 bushels at a cost of about 8 cents per bushel, paid dividends averaging $457, and had an average net profit left of $165, even tho one lost $900 because unable to obtain cars when needed. All but 2 of the 11 companies made profits, 5 paid stock dividends, and 2 patronage dividends.

In organization, a potato warehouse association is like a coöperative elevator. The difference is principally in their methods of doing business and of marketing their products.

LIVESTOCK SHIPPING ASSOCIATIONS

In 1918 about four hundred livestock shipping associations made reports to the Minnesota Central Coöperative Livestock Shipping Association at the Department of Agriculture of the University. About fifty more associations were supposed to be operating, but they made no reports. The figures in Table I are based on reports of 206 associations replying to an inquiry sent out by the Division of Research in Agricultural Economics. In 1914, only 82 associations replied to a similar inquiry; but 61 others were believed to be in existence. Later information shows that 5 of these 61 were probably not then operating. If so, then there were 138 associations in 1914. Of this number, 6 seem to have gone out of business, and at least 270 new ones seem to have been formed. No doubt others have organized and failed.

The receipts at the central market of the 206 associations making reports for 1917, totaled $20,664,000. This figure is to be compared with $5,750,000 for the 82 associations reporting in 1914. While much of this increase was due to higher prices for livestock, the number of carloads reported increased from 5,000 to 11,240. A fair estimate for the 400 associations in the state is 18,000 carloads selling at the central market for $33,000,000.

TABLE XVII

COMPARISON OF BUSINESS OF LIVESTOCK SHIPPING ASSOCIATIONS IN 1913, 1914, AND 1917

	1913*	1914†	1917
Number of associations‡	115	138	400
Number reporting	61	82	206
Gross receipts reported	$3,641,280	$5,750,530	$20,664,000
Carloads of stock reported	2,630	5,000	11,240
Total weight of stock reported	45,100,000	....	200,270,000
Average gross receipts	$59,692	$70,128	$100,310
Total expenses reported	$168,360	....	$569,850
Average number of carloads	45	61	55
Average expenses	$2,760	....	$2,782
Average expense per 100 pounds	$0.33	....	$0.29

* See Minnesota bulletin 146, "Statistics of coöperation among farmers," by L. D. H. Weld, 1913.

† See Minnesota bulletin 156, "Coöperative livestock shipping associations in Minnesota," by E. Dana Durand, 1916.

‡ Probable number.

Table XVII shows the total number of each kind of livestock, and the average per association. Hogs make the largest showing in number of head, and cattle in number of carloads. Compared with 1913, the associations are now shipping on the average slightly fewer hogs, calves, and sheep, but more than twice as many cattle. Some of the reports undoubtedly included some calves with cattle without indicating this fact. This is because many of the newer associations are in counties more given to cattle raising than to hog raising. Practically all the associations ship cattle and hogs, 55 per cent of them ship calves, and 74 per cent sheep. Of the 11,240 cars reported shipped, 5,400, or 48 per cent, were mixed cars.

TABLE XVIII

KIND AND AMOUNT OF LIVESTOCK SHIPPED, 1913 AND 1917

Kind of livestock	1917			1913
	Associations reporting	Number of animals	Average per association	Average per association*
Cattle	196	140,440	717	329
Hogs	198	399,600	2,020	2,372
Calves	113	47,100	416	465
Sheep	150	24,070	160	192
Total	203	611,220	3,011	3,100

* See Bulletin 146.

The expenses of livestock associations may be divided into central market expenses, freight, and home expenses. The central market expenses are principally commission fees, feed, yardage, and switching. The home expenses are mostly salaries of managers and reserve funds set aside to reimburse members for death or injury of animals during shipment. Table XIX shows that central market expenses and freight averaged $1,932 per association, or $34.15 per carload, and the home expenses $921 per association, or $16.50 per carload. Freight of course varies with the distance to market. All but a few of the associations ship to South St. Paul. The commissions paid are the regular fees charged all shippers. The manager's salary is most frequently paid as so much for 100 pounds home weight, 6 cents being the commonest rate. Other associations pay by the car, usually from $5 to $18. Others pay by the month, from $60 to $115. The reserve fund is usually 2 or 3 cents per 100 pounds home weight, or a percentage of gross receipts, usually 0.5 or 1 per cent.

TABLE XIX

ANALYSIS OF BUSINESS OF 146 LIVESTOCK SHIPPING ASSOCIATIONS IN 1917

	Totals	Average per association
Gross receipts at central market	$14,511,316	$99,393
Central market expenses and freight	284,135	1,932
Receipts at shipping point	14,227,176	97,461
Local or home expenses*	134,450	921
Net paid shippers	14,092,726	96,540

	Per car	Per cwt.	Per $100 gross receipts
		Cents	
Central market expenses and freight	$34.15	19.6	$1.96
Local expenses	16.50	9.5	0.93
Total expenses	50.65	29.1	2.89

* Includes amount put into reserves and all other deductions from gross receipts.

As to organization, a coöperative livestock shipping association is very simple. Little, if any, capital is required. A small membership fee pays all organization costs. No shares are sold. The association is seldom incorporated. The bookkeeping is simple. The manager notifies the shippers when the car will be ready, weighs, marks, and loads the livestock, accompanies the shipment to the central market (usually), obtains from the commission firm a record of the net weight, price received, and commission charged for each separate lot in the carload, divides the freight expense between the different lots according to weight, deducts his own commission and the payment to reserves, and then makes out to each shipper, along with a check for his net receipts, a statement covering all the above items of weight, price, and expense. In some of the markets the commission men even make out the checks and statements for the individual shippers. As to size, in 1917 the associations shipped on the average about $100,000 worth of livestock, or 3,000 head, in 55 cars. Most of the associations have from 100 to 300 members, but many associations smaller than this seem to be operating successfully. Other details as to organization, including a sample constitution, are given in Bulletin 156, which will be sent to anyone on request.

Obviously there has been rapid growth in this field of coöperation. The reason is not hard to find. Farmers always have made up carloads of stock among themselves. But in sections of the country where they sell only a few head at a time, and where half of the cars are mixed lots, as in most of Minnesota and Wisconsin, this is hard to arrange without an organization. Moreover, under such conditions the farmers have always been more or less at the mercy of the local buyers. Especially have the buyers taken undue profits at off seasons and for unusual types of livestock. They have frequently made large profits on calves. This is because farmers, and sometimes buyers too, do not know how such stuff will sell on the market, and too many buyers are often trying to make a living out of the business. The farmers have resented these things and have hastened to organize. Organization is easy and generally successful. Where local buyers have probably been taking from $40 to $75 a car for home expenses and profits, the associations are doing it for $16.50. Where buyers have been demanding margins of from 60 cents to $1 per hundred, the associations are doing the business for 29 cents per hundred. More than this, the farmers are learning more about prices and markets and grades of livestock, and are thus becoming more able to take advantage of a favorable market. By means of the telephone, a manager can frequently assemble a carload of livestock at a day's notice.

ESSENTIALS TO SUCCESS OF LIVESTOCK SHIPPING ASSOCIATIONS

Few kinds of coöperative organizations have more odds in their favor than livestock shipping associations. The farmers are vitally interested in their receipts from sales of meat animals. The business is simple, and more than this, is largely impersonal. Each shipper has a complete record of all transactions concerning his part of the shipment. The gains from coöperative dealing in this field are immediately apparent to everybody in the prices received for livestock. The accounting is also simple, and what is more important, it has to be done at the proper time and done right. No capital is required. No dividends are to be reckoned. Only producers have any interest in becoming members.

However, in spite of these favorable odds, associations are constantly failing or gradually quitting business. Following are the usual reasons for this:

1. *No real economic need for an association.*—The farmers already have a market, and this market is giving them service at so small a margin that they can better it little, if at all, by doing the work themselves. This seems to be the case at many shipping points in southern Minnesota. The farmers there are more likely to be producing fat stock of standard types, and they know the market quotations for the day. In consequence, the buyers have to be satisfied with narrower margins. Many new associations have been formed in southern Minnesota in the last three years, but they are not half so numerous here

as in the central counties. Most of the cars from central Minnesota are mixed. More cattle are shipped than hogs, and the cattle are assorted lots. On such offerings, local buyers often take wide margins. Two or three competing or supposedly competing buyers may demand wider margins than one. In fact, it is because there are too many buyers in some places trying to make a living out of the business that wide margins are taken. One coöperative association with one manager may thus do the work now done by several buyers, each trying to make from $50 to $150 a car.

2. *Not enough business.*—Livestock shipping associations do not need a large business nearly so much as do elevators, creameries, and stores. This is because no money is tied up in buildings and equipment. The expenses are mostly in exact proportion to the amount shipped. However, there are several important gains from a large amount of business. (a) Regular shipping days can be fixed. In small associations, the members notify the manager when they are ready to ship and the manager sets a day. Some may not wish to wait till then. Some may fail to deliver on the day set. The market may decline in the meantime. Stock may have to be held over and fed. (b) Shipping expenses and commission charges are higher on mixed cars. (c) Managers are usually paid a smaller commission if they handle a large amount of stock. (d) Better managers can be hired. Associations need, therefore, to bring in as many members as possible, and take all the business they can get. It is doubtful, however, if they should organize, depending largely on members who do their trading at another shipping point.

Farmers should not refuse to coöperate in this or any other business, however, merely because they can form only a small association. They may need to organize in such case to get any kind of market, or their association may do the work much more cheaply than existing agencies, altho at not quite so low a cost as some of the large associations elsewhere. Thus farmers in small settlements in the northern counties frequently do well to organize.

3. *Members not bound together closely enough.*—Members of livestock shipping associations have no invested capital to lose if the association breaks up. All they lose is their local market. Moreover, only occasionally do they have livestock to ship. Hence it is easy for them to drift away from the association and sell to local buyers, especially if they live about as close to other shipping points. It is very necessary, therefore, that members of a shipping association be thoroly loyal. It helps, also, to have the association thoroly organized, with constitution and by-laws carefully framed and carefully administered. The setting aside of a reserve fund also strengthens the membership bond somewhat. The reserve makes it easy to satisfy members suffering losses in shipments.

4. *Federation not fully enough developed.*—Most of the livestock-shipping associations in Minnesota ship to South St. Paul. The Minnesota Central Coöperative Livestock Shipping Association is now looking after the interests of shippers in this market, so far as lies within its power. The local associations should support the central association to the limit and provide it with enough means and power to fully protect their interests. Just at present, the association is trying to look after their interests in the matter of commission charges, especially on mixed cars, and in the matter of prices charged for feed at the yards.

COÖPERATIVE STORES

Table I lists the number of coöperative stores at 102 because this is the number of stores on the mailing list of the division. Only 58 of these reported, but no doubt most of the others are still operating. Furthermore, not all the new companies organized have been reported. Four new companies have been reported since the annual reports were asked for. In 1913, only 62 companies reported, and the total number was estimated at 120. In 1914 only 42 reported and the total number was estimated at 126. Quite possibly these earlier estimates are high, and the number of coöperative stores has not really decreased at all.

The volume of business of coöperative stores increased greatly between 1913 and 1917, owing principally but not altogether to higher prices for merchandise. Table XX, which combines the 42 reports that were complete and accurate, places the average volume of business at $72,042, as compared with $42,518 in 1913. This is an increase of 69 per cent. In the period from July, 1913, to July, 1917, retail prices rose 60 per cent in the United States.

TABLE XX

ANALYSIS OF BUSINESS OF 42 COOPERATIVE STORES, 1917

	Totals	Averages
Opening inventory	$602,429	$14,343
Paid for merchandise	2,639,016	62,834
Gross sales	3,025,759	72,042
Closing inventory	617,541	14,702
Gross profit	401,835	9,567
Total expenses	254,806	6,066
Net profit	147,029	3,501
Total dividends	63,674	1,516
Stock dividends	20,400	486
Trade dividends	43,274	1,030

Table XXI summarizes the reports for all the stores reporting each item. The net profits of 54 stores in 1917 were $190,157. The average net profits for the 42 stores were $3,501, the average stock dividends $486, and the average trade dividends $1,030. This still leaves an average surplus of $1,985, of which about $1,250 was transferred to reserves. Most of the rest was used to pay debts. Assuming the 42 stores to be a little larger and more prosperous than the average, the 102 stores believed to be operating in 1917 probably made a net profit of $300,000 and paid stock dividends of $42,000 and trade dividends of $130,000. A stock dividend of $486 is 4.6 per cent on the average paid-up capital of $10,600. If 6 per cent had been paid, the trade dividend would still have been $880 per store.

TABLE XXI

VOLUME OF BUSINESS REPORTED BY COOPERATIVE STORES, 1917

	Number reporting	Amounts reported
Paid-up capital	56	$590,669
Opening inventory	56	823,247
Paid for merchandise	52	3,386,368
Gross sales	56	4,008,877
Closing inventory	52	832,312
Gross profits	54	518,017
Total expenses	54	328,860
Net profit	54	190,157
Stock dividend	39	27,581
Patronage dividend	31	56,731
Transferred to reserves	37	46,203
Credit outstanding	52	374,464

The gross profits of $9,567 per store were 13.3 per cent of the gross sales, the total expenses were 8.4 per cent, and the net profits 4.9 per cent. The gross profits of 20 selected stores in 1913 were 14.4 per cent of gross sales, and in 1914, 16 per cent. Expenses were 10.8 per cent and 11.8 per cent in 1913 and 1914 respectively, and net profits 3.5 and 4.3 per cent. Altho expenses per store were $1,446 more in 1917 than in 1913, the percentage of expenses to gross sales was 2.4 less. The reason for this was of course the higher prices in 1917. Net profits were 1.4 per cent higher than in 1913. As a result, 69 per cent of the stores paid stock dividends in 1917 and 52 per cent paid trade dividends, as compared with 55 per cent and 38 per cent, respectively, in 1914. All but 21 per cent of the stores paid some kind of dividend and all but one made profits.

Apparently the coöperative stores prospered in 1917. They prospered also in 1913 and 1914, but not so greatly as in 1917. There can be no doubt that coöperative stores have been of considerable benefit to the farmers of Minnesota. It would be hard to find an equal number of privately owned stores, taken at random, that do business more efficiently or make larger profits than this group of coöperative stores. However, it is a business that has many difficulties for the inexperienced, and more attempts at coöperation fail in this field than in any of the others thus far discussed. Probably farmers are all the while learning better how to manage coöperative stores. At least, in 1913 the average age of 62 stores reporting was

5 years; in 1917 the average age of 55 stores was 8.4 years. New stores come and go, and once in a while an old one fails; but out of it all there remain a fairly constant number of stores that do a very good business.

In 1913, the coöperative stores averaged 104 members per company and farmers owned 86 per cent of the stock. All of those reporting limited votes to one per member, and all but 7 limited the number of shares per member. About two fifths of the business was furnished by non-members. Other details as to organization and management of coöperative stores, including a classification of accounts, will be found in Bulletin 171, which will be sent on request.

TABLE XXII

Disposition of Surplus of 58 Cooperative Stores, 1917

	Number reporting	Average amount reported
Surplus not distributed as dividends	12	$1,181
Stock dividend only	13	704
Trade dividend only	6	741
Stock and trade dividend	27	3,823
Stock and membership trade only	25	3,231
Non-membership trade also	2	2,953

ESSENTIALS TO SUCCESS WITH COÖPERATIVE STORES

Following are a few of the essentials to successful coöperation which have especial application to coöperative stores:

1. *An economic need stronger than required for most other kinds of coöperation.*—On reason for this is that most villages and small cities are already too well supplied with retail stores, and most of these are serving the public about as well as a rival coöperative store would do it. Another is that the members can not expect such large gains from this kind of coöperation as from most others. The average farm family in Minnesota, in 1917, probably spent between $300 and $500 for merchandise. The profits in 1917, after deductions were made for rebates to non-member patrons, amounted to about $25 per member. This is equal to a saving of 6 per cent on a $417 store bill. More than half of the $25 was left in the business as reserve and to pay off debt. A saving of 6 per cent is considerable, but $25 a year on a store bill will not make members as loyal as 2 cents a pound extra on butter, or 40 cents extra per hundred on livestock. For these reasons, farmers considering organizing a coöperative store must be very certain of a real economic need. Undoubtedly such a need exists in many places which have no coöperative stores to-day. This is especially likely to be true in the newer parts of the state. It is also true in many villages which have one or two stores and very little competition. In such cases, it is usually better if possible to

buy out a store already there. If this can not be done, then the new store must be certain of enough customers to enable it to compete with the old ones. In many cases, a coöperative buying club will serve the members for a while, and gradually open the way for a coöperative store later if one is really needed.

2. *Care in purchasing an existing store.*—A large percentage of the coöperative stores that have failed, have failed because they paid a high price for an unprofitable or even bankrupt business overstocked with unsalable goods. The farmers in every case before buying should call in a certified accountant and have him check the inventory and verify the statement of resources and liabilities.

3. *Expert management.*—The three essentials to good management of a store are, (a) keeping down expenses, (b) securing a rapid "turnover" of stock, and (c) extending credit wisely. To do all these things well needs special skill and special experience. Men with such skill and experience have to be well paid or they will go into business for themselves. The farmers' store that gets a good manager has little left to worry about.

Some believe that farmers' stores should give no credit whatever. Only one of the stores reporting operated on that basis. Two others had all their outstanding credit covered by personal notes. Ten of them had credit outstanding amounting to from 1 to 4 per cent of the amount of their gross sales in 1917. The average for all stores was 10 per cent of 1917 gross sales. A few of the larger stores had credit outstanding equal to the whole amount of their 1917 gross sales. No doubt the losses from this source have been greatly overstated by private owners of stores, but it is one of the things that is causing the coöperative stores to fail.

4. *Right distribution of profits.*—This includes limited stock dividends, and trade dividends to members and non-members, to non-members usually at a lower rate. An excellent plan is to let the rebate on non-member purchases accumulate on the books until they are enough to pay for a share in the company. This is a good way to build up the capital of the company.

FARMERS' MUTUAL INSURANCE COMPANIES

The number of farmers' mutual fire insurance companies in the state increased only from 154 to 159 between 1913 and 1916. The insurance in force, however, increased from $342,000,000 to $425,000,000. Some of the property insured is located in villages. Even in 1913, these companies were carrying more insurance policies than there were farmers in the state. The principal expansion of business has been due to the increased valuation of farm buildings. Only five counties in the state had no farmers' insurance companies in 1916, and these are mostly in the northern part of the state or near large cities. Stearns and Goodhue counties each had seven companies.

The reasons for the great success of farmers' mutual insurance companies are indicated in Tables XXIII and XXIV. The cost of carrying insurance in farmers' companies in 1916 was only 17 cents per $100 of insurance in force. Stock companies have in the past solicited farm business at the rate of 46 cents a year per hundred on three-year contracts. The farmers' companies paid out an average of 71.5 per cent of their receipts in losses during the five-year period, as compared with 52.5 paid in losses by the stock companies. The competition of the farmers' companies seems also to have forced the stock companies to offer continuously better rates. The reason why the farmers' companies handle business so cheaply is that they have no solicitor's fees to pay, no high salaries to pay to officers, and no profits to make for outside owners. The business is so simple that intelligent farmers with a fair education can handle it, that is, unless the companies grow larger than is good for them. Such men are willing to take on an outside interest, like helping run a farmers' insurance company, for a very small return. Stock companies, if they had more farm business, could perhaps reduce their premiums, but they could not reduce their cost of doing business.

TABLE XXIII

SUMMARY OF MINNESOTA BUSINESS OF TOWN MUTUALS, 1916*

Number of companies	159
Insurance written	$98,976,888
Insurance in force	425,504,730
Total receipts	712,606
Total loss payments	517,589
Total expenses paid	211,042
Average insurance in force	2,669,184
Average receipts per company	4,482
Average loss payments	3,255
Average expenses	1,327
Cost per $100 of insurance in force	0.17
Percentage of receipts paid in losses	72.7

* From 46th annual report of Commissioner of Insurance.

Most of the companies depend upon assessments for a large part of their income. A third of them collect fees and premiums enough in advance to cover losses. The former method seems to be well suited to the ordinary small farmers' company. Large companies no doubt find the other practice better.

Eight hail and cyclone insurance companies in the state call themselves "mutuals." Two of these do three fourths of the business. At least three of the others are actually owned and managed by farmers. The reciepts of the 8 companies in 1916 were $1,055,137, and 58 per cent of this amount was paid in losses.

TABLE XXIV

COST OF INSURANCE IN TOWN MUTUALS IN STOCK FIRE COMPANIES, FIVE YEARS' BUSINESS, 1912-1916

	Receipts—premiums, assessments, and policy fees	Paid in losses	Percentage of receipts paid in losses	Amount collected for each dollar paid in losses
Town mutual companies				
1912	$631,400	$454,286	72.0	$1.39
1913	637,635	513,973	80.5	1.24
1914	708,703	511,262	72.3	1.385
1915	675,064	413,620	61.5	1.635
1916	712,606	517,589	72.5	1.378
Total	$3,365,408	$2,410,730	71.5	$1.399
Stock fire companies				
1912	$7,939,821	$3,416,001	44.0	$2.315
1913	7,508,131	3,687,639	49.2	2.019
1914	7,620,121	3,951,469	51.8	1.93
1915	7,698,395	4,576,853	59.5	1.68
1916	7,988,369	4,717,905	59.0	1.69
Total	$38,754,837	$20,349,867	52.5	$1.902

In the fall of 1918, the farmers' insurance companies were confronted by the problem arising from the forest fires in Northern Minnesota which wiped out a large part of the insured property of several companies. The member companies of the State Association of Farmers' Mutual Insurance Companies, at the annual meeting held in Minneapolis in December, 1918, voted to accept these losses as their own and to raise the funds among themselves by contributions levied at the rate of 75 cents per thousand on their insured property. A plan of inter-insurance between the mutual companies in Northern Minnesota, and perhaps in other sections of the state, was also discussed.

FARMERS' MUTUAL TELEPHONE COMPANIES

Exactly 1,430 telephone companies with receipts of less than $3,000 during 1917 reported to the Railroad and Warehouse Commission. Perhaps a hundred more did not report. Some of these companies called themselves stock companies or partnership companies, but most of them reported as mutual or coöperative companies. The reports do not always make clear the real nature of many of these companies. Many of the smaller companies, usually those with annual receipts under $500, simply divide expenses among the subscribers, each farmer owning his own telephone and keeping his part of the line in repair. Companies larger than this sell stock to subscribers and occasionally pay dividends. Not all of these are now strictly coöperative. When the companies were first organized, all the subscribers were members and paid the same rates. But farmers coming into the neighborhood since have often wanted service without buying shares, and these have been charged a rental. Sometimes this rental has been high enough to reduce considerably the cost of service to the members. In most cases, from 90 to 100 per cent of the members and subscribers are farmers. Of the 1,430 reporting companies, at least 950 are coöperative in most respects.

The smaller companies usually have from 20 to 35 subscribers, who are assessed from $5 to $8 a year. The larger companies usually have from 100 to 300 subscribers, and the usual rate is from $10 to $12 a year. The annual revenues for the 950 companies probably amount to $1,200,000.

The small companies, if the lines are kept in proper repair and if they obtain proper connections with other lines, are in many ways most satisfactory. Farm populations naturally fall into neighborhood groupings along certain roads, in or around certain villages, churches, schoolhouses, or creameries. It should be the ideal of the farmers' telephone companies to connect all the people in one of these neighborhoods, and frequently the people of one or two other neighborhoods in addition. Furthermore, all the people living about one trade center should be brought into one system by proper connections of one sort or another. When one farmers' company spreads out over a whole township or county, the result too often is that the business gets too big to be properly handled by farmer managers.

OTHER FORMS OF CO PERATION

In addition to the main types of coöperation thus far discussed, there were in Minnesota in 1918 about two hundred and seventy-five other coöperative organizations handling farmers' business. Bulletin 146, compiled in 1913, lists 86 of these, but does not include buying clubs and horse-breeding associations. Several of these kinds of organizations are multiplying rapidly and no doubt will continue to do so. Others are still in the experimental stage. Following are the most important types:

Buying clubs.—The state of Minnesota has more than a thousand farmers' clubs of one kind or another, and a good many of these carry on more or less coöperative buying along with their social activities. Bulletin 167 describes in detail the organization and business methods of fifty of these clubs, which during 1916 bought merchandise worth about $100,000. This was estimated to be more than half of the coöperative buying done by all clubs in the state.

Lumber yards.—Probably 20 farmers' elevators handle lumber as one of their side lines. The combination seems to work satisfactorily. The same type of business organization fits both kinds of businesses, except that patronage dividends on lumber are always figured on a percentage basis. The federal Bureau of Markets has worked out an accounting system for a lumber business handled along with an elevator business. There are, however, probably 7 coöperative concerns in the state which ship little or no grain and call themselves farmers' lumber yards.

Wool-shipping associations.—The county agents of Minnesota reported six farmers' associations selling wool in 1917, one a strictly coöperative company, three of them pooling associations, and the other two, joint selling associations. Probably most of these were only temporary organizations. The six associations sold 65,000 pounds of wool at $38,000. In addition one or two produce associations handled wool as a side line. Unfortunately the activities of the federal government in buying wool in 1917 caused considerable losses to many farmers selling at private sale, and in some cases to those selling coöperatively.

Egg-shipping associations.—So far as known, no association is now shipping eggs exclusively. However, several coöperative creameries and produce companies handle eggs for patrons on a coöperative basis. This is undoubtedly a field in which coöperation should expand.

Horse-breeders' associations.—There are 135 associations in the state calling themselves horse companies or horse associations. Most of these bear the name of the village or community in which they are located. An inquiry made in 1914 showed that a large percentage of these were coöperative, and that most of the members were farmers. Their purpose is to improve the breeding of farm horses by the coöperative purchase of purebred sires.

County breeders' associations.—These are organizations of the livestock breeders in a county for purposes of buying and selling livestock and improving their herds. The principal activity of these associations at present is arranging combination sales and advertising them. Most of the members are cattle breeders; the others are hog breeders. Several different breeds are usually represented in one association, A small membership fee is charged. Other costs are shared by those benefiting from them. Twenty-four counties have these associations at present.

Breed associations.—These are organized like the county breeders' associations, except that the members all keep the same breed of livestock. A county in which the farmers keep several breeds of cattle may have several breed associations. Under such circumstances, this is a better kind of association than the county association. Some of these associations run combined advertisements in the agricultural journals. There are 28 breed associations at present, and the number will surely grow. Wisconsin has more than a hundred.

Neither breed nor breeders' association prospers unless a county has enough good herds to make the thing worth while. Associations have sometimes been organized in counties where there was nothing for them to do, and of course the result has been that they have failed.

Coöperative bull associations.—Minnesota has 8 of these associations at present. The oldest association is located in Douglas County. It owns 9 sires, each of which is used two years by one group of farmers living close together and then exchanged with another group. In this way, the association gets full use out of all its sires, and as a result can afford to buy animals of much better breeding. The costs are met by assessments on the members. Farmers' Bulletin 993, of the United States Department of Agriculture, gives full particulars concerning these associations.[4]

Cow-testing associations.—There were 26 cow-testing associations in the state in July, 1917, but the war took so many of the testers into service that only 15 were operating in December, 1918. The number is bound to increase again. Membership in cow-testing associations shifts considerably. Many farmers test one year and then skip a year or two years. The usual method is to pay according to the number of cows tested, but some associations are now charging a flat rate per member. The cow testers visit each farm once a month, weigh and test the milk of each cow, estimate the value of the feed consumed, and figure out the records for each cow. The testers are paid from $40 to $60 a month and board.

Milk marketing associations.—So far as known, Minnesota has no association which handles the milk clear through to the consumer. The Twin City Milk Producers' Association concerns itself with getting the best prices possible from the regular milk distributors. The members are assessed according to the amount of milk they deliver.

Farmers' meat-packing plants.—A farmers' meat-packing plant has been built at Newport, but is not yet operating. The two earlier attempts to establish coöperative meat-packing plants in Minnesota failed, one plant closing down and the other passing into private hands. Four have been started in Wisconsin, one of which is at New Richmond just across the state line. The first plant started, at La Crosse, closed down after two years. It made the mistake of paying too much for an old packing plant. At least one of the other plants is very short of funds for carrying on its business, and apparently unwilling to ask the members for more funds. The cost of selling stock in these companies has ranged from 15 cents to about 25 cents on every dollar of stock sold.[5] A sensible plan for the people of Minnesota to follow is to await the results of the three remaining experiments in Wisconsin. Meat packing is a complicated business. The local market for meat is not so good as some farmers have imagined. It will not take all the meat of certain kinds that the farmers produce, and it demands other meats which the farmers do not produce in large enough quantities. When a farmers' packing plant has to look for outside markets, it meets very severe competition.

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[4] Winkjer, J. G. "Coöperative bull associations." U. S. Dept. of Agr., Farmers' Bull. 993, 1918

[5] Wisconsin Bulletin 282.

Other types of coöperative associations.—Minnesota also has a Coöperative Dairies Association, organized in 1907 to help the coöperative creameries market their butter to better advantage; an Equity Grain Exchange, Livestock Exchange, and Wool Exchange; at least four fruit-shipping associations; two farmers' banks which are more or less coöperative; one coöperative laundry; several community mills; and three farmers' hail and cyclone insurance companies. Not all of these are strictly coöperative in all particulars.

PROSPECTS FOR COOPERATION

When farmers organize and market their own produce, they replace the local middlemen with middlemen of their own. They elect a president and board of directors and hire a manager, and these men do their buying and selling for them. When the regular middlemen do this, they do it in the hope of making wages of management plus a profit. The hired manager does his work for a salary, or wages of management. The *profits* go to the members, because they take the risks. Moreover, the hired manager does not do all the managing. The officers of the company also take a hand in it. Farmers are willing to do this kind of work cheap. There are always some of them whose mental energy is not all used up in running their farms who are very glad of a chance to use part of it in looking after something outside of their own particular farm, and the only pay they expect in most cases is the better market they get for their own produce as a result. The hired manager, if he is as capable as he should be, will want as good pay for the service he renders as he would make if he were working for himself; but he needs to be paid for only that part of the managing which he does. The rest of it the officers do and do cheaply. The members save by coöperating because they take the risks and get the profits, and because they contribute their own services.

On the other hand, one must not forget that sometimes the services of farmers in marketing farm products are not so economical after all. Where the officers do not understand the business they are handling, their services may be dear at any price. Moreover, hired managers do not always work so hard for their employers as the regular middlemen do for themselves. For these two reasons, many coöperative enterprises are not so efficiently operated as some private concerns in the same towns. This is likely to be the case where coöperation is breaking into new fields of business or new territory. After a while, however, enough members learn the business, and enough hired managers become trained, that the farmers can compete on even terms, even in the matter of efficiency, with the regular middlemen. The coöperative companies of Minnesota, taken as a whole, are surely as well managed as the private companies.

Another advantage which comes to producers when they coöperate is that all of them soon come to know a good deal more about the marketing of farm products than they formerly did. This enables them to take advantage of the market at every turn, to put their products on the market at the right time, and more important than all else, to produce what the market demands. The result of this is that they are soon turning out better and more uniform products, and getting much better prices.

As long as farmers depend on the regular middlemen, they can never feel entirely certain that they are not being exploited somewhat. Where competition is active, they are usually safe enough, but they can never be really sure that competition is active. Local middlemen often find it is to their advantage not to compete, especially in the matter of price. However, when people do their own buying and selling, and do it on a democratic basis, they can feel perfectly sure that no local agencies are exploiting them, and this feeling of security is worth much to them and to the people who have to get along with them.

One great reason for the waste in buying and selling at present is that there are too many local middlemen. It would be better in many towns if there were only one elevator and one grocery store. But as long as these are private concerns it is never safe to let one of them corner all the business. It is perfectly safe, however, to let one coöperative concern absorb the whole business of a community as long as it is managed on a truly coöperative basis and membership is open to all. There are many places in Minnesota where this is exactly what has happened, or is happening, and the result is that the people are getting the best and cheapest service to be found anywhere in the state.

Great wastes also result because there are too many farmers each working almost entirely by himself. There are a great many things which they need to do that few of them can afford to do by themselves, or that cost a great deal when done in that way, which can be done easily and at little cost when all do them together. Only a few farmers can spare the money to buy a purebred sire of excellent breeding, but twenty-four of them can easily buy six and get ten years' use out of each of them. Not many farmers can go to the trouble and expense of keeping milk and feeding records for their cows; but two or three dozen of them can coöperate and hire a cow-tester to do it for them. This is only a beginning. A large part of the great advantages which are possible from large-scale production in the cities, and from applying scientific methods to trade and industry, are quite possible in the country if farmers will combine and have these things done in coöperation.

The future in farming, just as in city trades and industries, promises therefore to include a considerable amount of coöperation along with private and public operation and management. But in just what fields and along just what lines it will develop, no one can definitely say. The proper course to follow is to go as far as possible with the kinds of coöperation that have been tried and found to work and to try out carefully all the likely-looking new kinds, not going too fast at the start with any of them, but first setting up a few associations as experiments, so as to find out if they will work, and what is the best way to organize and manage them. Some kinds of coöperation will be tried that will not work. Others will work after a while when the proper methods have been discovered and learned. Others will work almost from the start. In the end, we will know much better than we do now just what is the proper sphere for coöperation. We can safely predict even now that this sphere will have its limits.

In some men's minds, the all-important thing is to get the farmers to organize. It is doubtful, however, if too much pressure should be brought to bear to get the farmers in any particular community to form a company. If general campaigns are conducted in favor of all kinds of farmers' coöperation, and in favor of particular kinds that are succeeding at the time, then the intelligent people in a community will think about their local situation and decide whether a coöperative company is needed and whether it will succeed or not. In most places, there are county agents who will help them to decide this question. The points which they need to consider are set forth in this and similar bulletins issued by this division. Any additional information they need will be gladly sent upon request. The Department of Agriculture of the University of Minnesota will try to help them organize. It will send men to help them if they ask it. However, it will not go out into particular communities and say to the people: "You ought to organize a coöperative company." It has no right to say this because it does not know the community and the local conditions well enough. Only men who have lived in the community for several years know that. The first move toward coöperation should therefore always be made at home.

There are men, however, who will go out and tell people everywhere that they ought to organize. These are the promoters. There are two kinds. The old-fashioned promoter was in the pay of outside concerns having something to sell. He organized coöperative creameries so that he could sell them butter-making outfits at double their value, or horse-breeding associations so that he could sell them stallions at three or four times their value. About 1,500 creameries were promoted by these men in Wisconsin alone, at a cost to the people of the state of about $5,000 per creamery. By 1893, about $7,000,000 was tied up in idle promoted creameries in Wisconsin alone.[6] Minnesota was in large part saved from this calamity by the work of one man in the College of Agriculture, who got out posters and circulars warning the farmers against the promoter. As a result, 76 per cent of the creameries in Minnesota are now coöperative, as compared with only 45 per cent in Wisconsin. Kansas has a law which provides that the state must approve of any proposed creamery before it is built. The Wisconsin Dairymen's Association at its recent convention passed a resolution in favor of such a law for Wisconsin.

The modern type of promoter gets his pay from the commissions he gets for selling the stock of the new company. The promoters received $37,000 for selling the stock of the La Crosse meat-packing plant in Wisconsin. Where men are paid to do such work, there is always great danger that they will sell enough stock to start a company even tho the people do not want it enough to support it afterwards. A safer plan is for the farmers to do their own promoting. If they can not do it, then the community is probably not ready to coöperate. Conscientious promoters of course will not sell stock for a coöperative company unless they are quite sure that it will succeed, just as conscientious agents will not sell books to people who ought to use their money for something else. If coöperation is going to grow as it should in Minnesota, either the professional promoters must all become conscientious about their work, or laws must be passed controlling their activities. Already the Federal Farm Loan Bank has ruled that no charter shall be issued to a bank whose shares have been sold on commission.

The Division of Research in Agricultural Economics wishes to help farmers of Minnesota with their coöperation and their marketing problems in every way it can. It has already begun a study of coöperative potato warehouses and produce shipping associations. It hopes shortly to undertake investigations of several other new types of associations with a view to discovering what can be done with them. Coöperative companies are becoming so thick in some parts of the state that they are encroaching upon each other. The division wishes to make a study of competition between coöperatives to see how it can best be controlled. It would like also to study the unfair practices resorted to by rival companies to put coöperative companies out of business. An investigation of immediate importance is the possible improvement of our present system of distributing milk in cities. During the war, it has been impossible to do these things because most of the investigators in the country have been in the service of the government. From now on, more helpers will be available.

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[6] Wisconsin Bulletin, 282, p. 41.

LAWS OF MINNESOTA AFFECTING FARMERS' COÖPERATION

LAWS OF 1913, GENERAL STATUTES, CHAPTER 58

GENERAL COÖPERATIVE ASSOCIATIONS

6479. *Formation—Purposes*—A co-operative association may be formed for the purpose of engaging in any lawful mercantile, manufacturing, or agricultural business. Its certificate of incorporation shall be filed for record with the register of deeds of the county of its principal place of business, and thereupon it shall become a corporation. A majority of the incorporators shall be residents of the county of its principal place of business, and its duration without renewal shall not exceed twenty years.

6482. *Officers—Management*—Every such association shall have a president, a treasurer, and not less than three directors, who shall together constitute a board of managers and conduct its business. Such officers shall be chosen annually by the stockholders and hold their offices until others have been chosen and qualified. The association shall make its own by-laws, not inconsistent with law, and may therein provide for any other officers deemed necessary, and the mode of their selection. It may amend its certificate of incorporation at any general stockholders' meeting, or at any special meeting called for that purpose, upon ten days' notice to the stockholders.

6483. *Capital—Limit of interest—Shares*—The amount of capital stock shall be fixed by the certificate of incorporation, which amount and the number of shares may be increased or diminished at a stockholders' meeting specially called for that purpose, but the whole amount of stock shall never exceed one hundred thousand dollars, and, in case of a creamery association, shall not exceed twenty-five thousand dollars. Within thirty days after the adoption of an amendment increasing or diminishing its capital, it shall cause the vote so adopting it to be recorded in the office of the register of deeds where its original certificate is on record. No share shall be issued for less than its par value, and no member shall own shares of greater par value than one thousand dollars, or be entitled to more than one vote. It may commence business whenever twenty per cent of the stock has been subscribed for and paid in, but no certificate of shares shall be issued to any person until the full amount thereof has been paid in cash, and no person shall become a shareholder therein except by consent of the managers.

6484. *Liability of officers—Dissolution*—If such board of managers, or the directors or officers having control of such association, for five consecutive years after its organization shall fail to declare a dividend upon its capital or shares, five or more stockholders, by petition setting forth such facts, may apply to the district court of the county of its principal place of business, for its dissolution. If, upon hearing, the allegations of the petition are found to be true, the court may adjudge a dissolution of the association.

6485. *Distribution of profits*—The profits on the earnings of such association shall be distributed to those entitled thereto by its by-laws, and in the proportions and at the times therein prescribed, which shall be as often as once in twelve months.

6486. *Annual report to dairy and food commissioner*—Every creamery association, on or before December 30 in each year, shall make report to the state dairy and food commissioner, or such officer as may at any time, by law, be given the supervision of dairy products. Such report shall contain the name of the corporation, its principal place of business, the location of its creamery, and the number of pounds of butter or other dairy product manufactured by it during the preceding year.

LAW APPLYING TO COÖPERATIVE ASSOCIATIONS FORMED FOR THE PURPOSE OF MARKETING PRODUCTS OF OTHER COÖPERATIVE ASSOCIATIONS

6487. *Associations for sale of certain products*—That any co-operative associations may be formed for the purpose of selling and otherwise disposing of any product of any manufacturing or agricultural co-operative association organized under the laws of this state. Its certificates of incorporation shall be filed for record with the secretary of state, and thereupon it shall become a corporation. A majority of the incorporators thereof shall be residents of this state and its duration, without renewal, shall not exceed twenty years.

6488. *Same—Officers—By-laws—Amendment of articles—Capital stock—Dissolution—Annual report*—Every such association shall have a president, a treasurer, and not less than three directors, who shall together constitute a board of managers and conduct its business. Such officers shall be chosen annually by the stockholders, and shall hold their offices until others shall be chosen and qualified. The association shall make its own by-laws, not inconsistent with the law, and may herein provide for any other officers deemed necessary, and the mode of their selection. It may amend its articles of incorporation at any general stockholders' meeting, or at any special meeting called for that purpose, upon ten days' notice to the stockholders. The amount of capital stock shall be fixed by the articles of incorporation, which amount and the number of shares may be increased or diminished at a stockholders' meeting, specially called for that purpose, but the whole amount of stock shall never exceed one hundred thousand dollars. Within thirty days after the adoption of the amendment increasing or diminishing its capital stock, it shall cause the vote so adopting it to be recorded in the office of the secretary of state. No share shall be issued for less than its par value and no member shall own shares of a greater par value than one thousand dollars, or be entitled to more than one vote. It may commence business whenever 20 per cent of the authorized stock has been subscribed for and paid in, but no certificate of shares shall be issued to any person until the full amount of such subscription therein has been paid in cash, and no person shall become a shareholder therein except by the consent of the managers. If such board of managers, or the directors or officers having control of such association, for five consecutive years after its organization shall fail to declare a dividend upon its capital or shares, five or more stockholders, by petition, setting forth such fact, may apply to the district court of the county wherein is situated its principal place of business in this state, for its dissolution. If, upon hearing, the allegations of the petition are found to be true, the court may adjudge a dissolution of the association. The profits on the earnings of such association shall be distributed to those entitled thereto by its by-laws and in proportions and at the times therein prescribed, which shall be as often as once in twelve months. Every corporation organized under the terms of this act shall on or before December 30th, in each year, make a report to the state dairy and food commissioner; such report shall contain the name of the corporation, its principal place of business in this state, and generally a statement as to its business, showing total amount of business transacted, its profits and losses.

6489. *Same—Stock in other corporations*—Any corporation heretofore or hereafter organized under the provisions of section 3073, Revised Laws of 1905 (6479), or chapters 276 or 313, General Laws 1905, is hereby authorized, in addition to those other powers to it granted, upon an affirmative vote of a majority of its directors or other governing body, had at any regular meeting or any special meeting called for that purpose, to subscribe to the capital stock of any corporation organized under the provisions of this act, pay for the same, and thereafter, in like manner, vote the same and exercise all the usual powers of a stockholder in a corporation, subject to the limitations herein set forth.

LAW APPLYING TO RURAL TELEPHONE COMPANIES

6480. *Formation—Rural telephone business—Powers*—Seven or more persons of lawful age, inhabitants of this state, may, by written articles of agreement, associate themselves together for the purpose of trade or for carrying on an (any) lawful mercantile, manufacturing, agricultural or rural telephone business within this state; and when such articles of association shall have been executed and recorded in the office of the clerk of the city or town in which the business is to be carried on, such persons shall be and become a corporation, and enjoy all the powers and privileges, and can buy and hold stock in other corporations organized for the same general purpose, and be subject to all duties, restrictions and liabilities set forth in all general laws in relation to similar corporations, except so far as the same may be limited or enlarged by this act.

6481. *Same*—A co-operative association may be formed for the purpose of engaging in any lawful mercantile, manufacturing, agricultural or rural telephone business. Its certificate of incorporation shall be filed for record with the register of deeds of the county of its principal place of business, and thereupon it shall become a corporation. A majority of the incorporators that reside in this state shall be residents of the county of its principal place of business, and its duration without renewal shall not exceed twenty years.

6490. *Rural telephone companies—Place of business—Stockholders' meetings, where held*—All rural telephone companies or associations, organized or incorporated under any of the laws of this state shall have its principal place of business in the township, city or village designated in is articles of incorporation as such; provided that any officer of such company may transact the business pertaining to his particular office in any township, city or village into which such township, city or village, the lines of such company extend, or in any city or village within any such township; and provided further that any such rural telephone company whose lines extend into more than one township may hold its stockholders' meeting in any township, city or village through or into which its lines extend or in any city, or village, within any such township as its stockholders, or members may from time to time designate at a previous annual meeting or a special meeting called for that purpose, but until a different place is so designated the township, city or village named as its principal place of business shall be the place for holding all stockholders' meetings thereof and when a place is so designated it shall be and remain the place for holding all stockholders' meetings until again changed by a vote of the stockholders as aforesaid and it shall be the duty of the officer calling any such meeting to procure a place of meeting in the township, city or village so designated; and state the location of same in his notice of the meeting.

LAWS OF 1919, GENERAL STATUTES, CHAPTER 382

Secton 1. *Co-operative associations—Who may organize—Purposes*—A co-operative association, society, company or exchange may be formed for the purpose of conducting any agricultural, dairy, mercantile, mining, telephone, manufacturing, or mechanical business upon the co-operative plan, and in addition to other powers, such society, association or exchange, shall have power to buy, sell or deal in its own products, the products of its individual members, the products of any other co-operative association whether organized under the provisions of this Act or otherwise. It shall be lawful for such association or associations to sell its own products as well as the products of its members for them, either individually or collectively, and to negotiate the price at which such products may be sold either for itself or for its members, individually or collectively, as the case may be. For the above purposes it shall have the power to purchase and hold, lease, mortgage, encumber, sell, exchange and convey such real estate, buildings and personal property as the business of the association may require; also to erect buildings upon its own lands or leased grounds. For the purpose of this Act the words "company", "corporation", "exchange", "society", or "union", shall be construed to mean an association. No corporation or association hereafter organized or doing business for profit in this state shall be entitled to use the term "co-operative" as part of its corporate or business name or title, unless it has complied with the provisions of this Act. Any corporation or association violating the provisions of this section may be enjoined from doing business under such name or title at the instance of any stockholder of any association legally organized hereunder.

Sec. 2. *Articles of incorporation—Contents and filing*—Persons forming an association under this Act shall sign and acknowledge written articles of incorporation specifying:

(a) The name of the association, the general nature of its business and the principal place of transacting the same. Such name shall distinguish it from all other corporations, domestic or foreign, doing business in the state and shall be preserved to it during its corporate existence.

(b) The period of its duration, if limited, shall not exceed Thirty years (30) without renewal.

(c) The name and place of residence of the incorporators. Associations with a capitalization of Fifty Thousand Dollars ($50,000.00) or less shall have at least seven (7) incorporators and associations with a capitalization of more than Fifty Thousand Dollars ($50,000.00) shall have at least fifteen (15) incorporators, a majority of whom in both cases shall be residents of the state.

(d) In what board its management shall be vested, the date of the annual meeting at which it shall be elected, and the names and places of residence of those composing the board until the first election, a majority of whom shall be residents of the state.

(e) The amount of capital stock if any; how the same is to be paid in, the number of shares into which it is to be divided and the par value of each share.

(f) The highest amount of indebtedness or liability to which the association shall at any time be subject, which may be fixed in a stated amount or by percentage of its paid-in capital.

(g) To amend its articles of incorporation, as hereinafter provided, and it may also contain any other lawful provision defining and regulating the powers or business of the association, its officers, directors, trustees, members and stockholders.

Articles of incorporation of any association organized under this act, or amendments to such articles of incorporation, shall be published in the same manner as provided in Section 6149, Chapter 58, General Statutes of 1913, relating to corporations. The original articles of incorporation, or a certified copy thereof, verified as such by the affidavits of two of the signers, shall be filed with the Register of Deeds of the county of the principal place of business of the association, if incorporated for Twenty-Five Thousand Dollars ($25,000.00) or less, and with the Secretary of State if incorporated for more than Twenty-Five Thousand Dollars ($25,000.00). If the articles of incorporation are filed with the Secretary of State, a certified copy shall be filed and recorded in the office of the Register of Deeds of the county in which the principal place of business of the association is located. For filing the articles of incorporation with the Secretary of State there shall be paid to the State Treasurer a fee of Ten Dollars ($10.00) and for amendments to such articles Five Dollars ($5.00).

Sec. 3. *Capital—Limit of interest—Vote*—The amount of capital stock shall be fixed by the articles of incorporation. The amount of stock and the number of shares may be increased or diminished at any regular meeting of the stockholders or at any meeting of the stockholders called for such purpose in the manner hereinafter provided for amending the articles of incorporation. Within Thirty (30) days after the adoption of an amendment increasing or diminishing its capital the vote by which such amendment was adopted shall be recorded in the office where the original articles of incorporation were recorded, as provided in Section 2 of this Act. The association may commence business whenever twenty per cent (20%) of the capital stock has been subscribed and paid in, and the amount of capital stock outstanding shall at no time be diminished below twenty per cent (20%) of the amount of the authorized capital. No share shall be issued for less than its par value nor until the same has been paid for in cash or its equivalent and such payment has been deposited with the Treasurer. The association may limit the amount of stock or the number of shares which may be issued or owned by one person but in no case shall the person be allowed to own or hold more stock than would represent the value of One Thousand Dollars ($1,000.00) of the par value of such stock. No stockholder shall be entitled to more than one vote, which shall be in person or by mail as hereinafter provided, and no stockholder shall be allowed to vote by proxy. No person shall become a stockholder of any association organized under this Act by transfer of stock except by consent of the Board of Directors, and the By-Laws may provide that the association shall have the first privilege of purchasing stock offered for sale by any stockholder. Any stock so acquired by the Board of Directors for the company may be held as Treasury stock or may be retired and cancelled.

Any stockholder who knowingly and intentionally violates the provisions of this Act or the provisions of the By-Laws adopted by any association organized under this Act may be required by the Board of Directors to forfeit his stock, in which case the Board of Directors shall refund to such stockholder the par value of his stock, or in case the book value of such stock shall be greater than par value, he shall be paid the amount of the book value of same. Stock so forfeited shall be retired and cancelled by the Board of Directors and such stockholder shall have no further rights or benefits in such association.

At any regularly called general or special meeting of the stockholders a written vote received by mail from any absent stockholder certified to and signed by him, may be read in such meeting and shall be accepted as the vote of the stockholder so signing; provided, however, that such stockholder has had due and previous notice, as elsewhere provided in this Act, and that a notice containing the exact text of the motion or resolution or amendment has been mailed to him at his last known postoffice address and that a copy of same is forwarded with and attached to the vote so mailed by absent stockholder. The Board of Directors may cause a referendum vote to be taken by mail upon any action or recommendation of the Board or for the purpose of electing members upon the Board of Directors, subject to the same regulations as above provided.

Sec. 4. *Stockholders' meetings—regular and special*—Meetings of the stockholders shall be held annually at the principal place of business of the association at such time as shall be designated by the By-Laws. At such annual meeting, reports covering the business of the association for the previous fiscal year and showing the condition of the association at the close of the fiscal year shall be submitted to the stockholders by the officers, and directors shall be elected for the ensuing year. The Secretary shall cause notice of such meeting to be published in a daily or weekly newspaper published in the principal place of business of such association and being qualified to publish legal notices and such notice shall appear in at least two consecutive issues of such newspaper in the case of a weekly paper and in the case of a daily paper once each week for two consecutive weeks, previous to such meeting. Or notice of such meeting may be given by mailing notice of such meeting to each and every stockholder at his or her last known postoffice address not less than ten (10) days previous to the date of such meeting.

Special meetings of the stockholders may be called by a majority vote of the directors or upon written petition of at least ten per cent (10%) of the stockholders, in which case it shall be the duty of the President to cause notice of such meeting to be made as above provided. Such notice shall state the time, place and purpose of such meeting and shall be issued within ten (10) days of the date of the presentation of such petition and such meeting shall be held within thirty (30) days of the date of the presentation of such petition. Notice of regular or special meetings having been mailed to the stockholders of the association or published in a daily or weekly newspaper as above provided, the Secretary shall execute a certificate stating the date and manner in which such notice was issued and an exact copy of such notice, and failure of any stockholder to receive such notice shall not invalidate any action taken by the stockholders at such regular or special meeting.

Sec. 5. *Quorum*—Except in cases where this Act requires a majority vote of all stockholders, the number of stockholders required to be present in person or represented by mail vote at any regular or special stockholders' meeting to constitute a quorum for the transaction of business shall be a majority of such stockholders when the total number does not exceed one hundred (100), and at least ten per cent (10%) of the total number of stockholders in all other cases, which shall not be less than fifty (50); but four hundred (400) stockholders present in person shall constitute a quorum in any association. The fact of the attendance of a sufficient number of stockholders to constitute a quorum shall be established by a registration of the stockholders of the company, which registration shall be verified and certified to by the President and Secretary of the association. No action of any association organized under this act shall be valid or legal unless there is a quorum present, as above provided, at the meeting at which such action is taken.

Sec. 6. *Directors—Election of—Duties—Officers*—Every association shall be managed by a board of not less than five (5) directors, who shall be members of the association and who shall be elected by the stockholders by ballot at such time and for such period as the By-Laws shall prescribe. The officers of the associations shall be a president, one or more vice-presidents, a secretary and a treasurer, who shall be elected annually by the directors. Each officer shall be a director of the association. The office of secretary and treasurer may be combined, and when so combined the person filling the office shall be termed "secretary-treasurer." A quorum of the stockholders shall have power at any regular or special stockholders' meeting, regularly called, to remove any director or officer for cause and fill the vacancy. The By-Laws shall specify the manner of nominating and electing the directors.

Sec. 7. *Earnings—Reserve fund—Distribution*—The stockholders may set aside all of the earnings of the first and second fiscal years of the association for the purpose of creating a reserve fund and the directors shall transfer to said reserve fund at least ten per cent (10%) of the annual net earnings until an amount has accumulated equal to thirty per cent (30%) of the paid-up capital stock, which reserve fund may be used in the business of the association, the same as paid-up capital. When recommended by the directors, the stockholders at any annual meeting, or at a special meeting called for that purpose, may increase such reserve fund out of the annual net earnings to one hundred per cent (100%) of the paid-up capital stock. A portion of the net profits not exceeding five per cent (5%) may be used as an educational fund for teaching co-operation. Annual dividends shall not exceed eight per cent (8%). Additional net profits shall be disbursed by uniform dividends based upon the amount of purchases from the association by stockholders and upon the wages and salaries received by the employees. Non-stockholders shall receive dividends upon purchases equal to one-half the amount paid to stockholders which may be paid in the capital stock of the association. In productive associations, such as creameries, canneries, and elevators such dividends shall be based upon raw material delivered instead of upon goods purchased, and if an association is both a selling and a productive concern the dividends may be upon raw material delivered and goods purchased. Distribution of net earnings shall be made as often as the directors shall determine, which shall be at least once in each year, if the net earnings after the amount required to be set aside as a reserve fund has been deducted, are of sufficient amount to pay such dividend, and not otherwise. If the Board of Directors of any association shall authorize the payment of dividends on the paid-up capital stock in excess of eight per cent (8%), such act shall operate as a vacation of office of each director or officer voting for, authorizing, or in any manner sanctioning such payment and as a disqualification of such director or officer from holding any office of the association for a period of three years thereafter. Whenever any such association for a second time authorizes the payment of dividends on the paid-up capital stock in excess of eight per cent (8%), the secretary of state may institute the proper proceedings for the forfeiture of the charter of such association.

Sec. 8. *Purchase of going business—Payment—Special stock issue*—Whenever any association shall purchase the business of another association, corporation firm, or individual, it may pay for the same in whole or in part by issuing in payment therefor shares of its capital stock to an amount, which, at par value, would equal the fair market value of the business purchased; and in such case the sale to the association of such business shall be equivalent to payment in cash for the shares of stock so issued. In case the cash value of such purchased business exceeds one thousand dollars, the directors of the association are authorized to hold the shares in excess of one thousand dollars ($1,000.00) in trust for the vendor, and dispose of the same to such persons, and within such times, as may be mutually satisfactory to the parties in interest, and to pay the proceeds thereof as currently received to the former owner of such business. At any regular meeting of the stockholders or at any regularly called special meeting, at which a quorum of stockholders shall be present or represented by mail vote, any association may, by a majority of the votes of the stockholders present and voting or represented by mail vote, subscribe for shares and invest the reserve fund or any portion thereof in the capital stock of any other co-operative association or for the purpose of purchasing any going business permitted under its articles of incorporation.

Sec. 9. *Promotion expense limited*—None of the funds of any association organized under this act shall be used, nor shall any stock of such association be issued in payment of any promotion of such association or commissions, salaries, or expenses of any kind, character or nature whatsoever; except that a sum not to exceed five per cent (5%) of the par value of stock sold may be used by committees elected by the stockholders for selling or soliciting for the sale of stock or for hiring responsible salaried solicitors for such purpose, Provided, that associations operating in more than one county may expend ten per cent (10%) for such purpose if incorporated for less than one hundred thousand dollars ($100,000.00) and over fifty thousand dollars ($50,000.00). Associations incorporated for more than one hundred thousand dollars ($100,000.00) shall be governed by the laws of the state regarding the sale of stock by other corporations.

Sec. 10. *Annual reports—Form of filing*—Every association organized under this act shall be required to file with the Department of Agriculture, and every creamery or other association manufacturing or handling dairy products, whether organized under this act or otherwise, shall file with the Dairy and Food Commissioner each year a report of its business for the last fiscal year, which report shall be made on or before the first day of March or at the close of the fiscal year. Such report shall contain the name of the association, the amount of its authorized and paid-in capital, the names of its officers and directors, a statement of its resources and liabilities and such other information as may be required by the departments with which such report shall be filed.

Sec. 11. *Associations heretofore organized may come under this act*—Any co-operative corporation or association heretofore organized and doing business under prior statutes, or which was doing business under an attempted organization thereunder, which retains the same name or title, may come under the provisions of this act and be bound thereby upon filing with the proper official a copy of the resolution authorizing such action adopted by the stockholders of such corporation or association in the manner provided for the adoption of amendments. There shall be filed at the same time a copy of the articles of incorporation of said corporation or association. The place for filing such resolution and articles and the fees to be paid therefor shall be the same as for new associations organized under this act. Co-operative associations organized under the laws of other states may become subject to the provisions of this act by proceeding as provided by this section.

Sec. 12. *Amending articles of incorporation.*—The articles of incorporation of any association organized under this Act or which may elect to come under the provisions of this Act may be amended so as to change its corporate name or title, or so as to increase or diminish its capital stock, or to change the number and par value of the shares of its capital stock, or in respect to any other matter which the original articles of incorporation of the same kind might lawfully have contained, in the following manner: The Board of Directors, by majority vote of its members, may pass a resolution setting forth the full text of the proposed amendment and also the full text of such section as may be repealed by such amendment. Upon such action by the Board of Directors, notice shall be mailed to each and every stockholder containing a copy of the resolution so adopted, the full text of the proposed amendment, and also the full text of such section or sections as may be repealed by such amendment. Such notice shall also designate the time and place of the meeting at which such proposed amendment shall be considered and voted upon, in the same manner as elsewhere provided in this Act. If a quorum of the stockholders is registered as being present or represented by mail vote at such meeting, a majority of the members so present or represented by mail vote, may adopt or reject such proposed amendment. In case such amendment is adopted, it shall be filed and recorded with the office in which the original articles of incorporation are filed or recorded, together with a copy of the notice given to stockholders and the certificate of the President and Secretary verifying the action of the meeting at which such amendment was adopted.

Sec. 13. *Companies excepted*—Existing laws relative to the incorporation and management of rural telephone companies and co-operative creameries, except as specifically repealed by Section 14 of this Act, shall remain in force and shall not be affected by any of the provisions of this Act; provided, however, that any such rural telephone company or co-operative creamery organized under the provisions of existing laws may continue to operate thereunder until they shall come under the provisions of this Act by complying with Section 11 thereof.

Sec. 14. *Laws repealed*—Sections 6479, 6481, 6482, 6485, 6488, 6489 if Chapter 58, of the General Statutes of 1913, and amendments thereto, insofar as they conflict with the provisions of this act, are hereby repealed, but any corporation or association incorporated and operating under the provisions of said sections shall continue to be governed thereby until they elect to come under the provisions of this act.

GENERAL STATUTES, CHAPTER 126

Section 1. *Extension of time for closing affairs of certain dissolved co-operative associations*—Where any co-operative association other than a co-operative association having the power of eminent domain, which has been dissolved more than three years by expiration or forfeiture of its charter, did not fully close its affairs and convey all its property within the three-year limit prescribed by section 6198 of General Statutes of 1913, the time so limited is hereby extended for two years from and after the passage of this act for the purpose of closing up the affairs of any such co-operative association and conveying its property.

Sec. 2. *Conveyances legalized*—Any and all conveyances of property by any such co-operative association after the expiration of the three-year limitation prescribed by section 6198 of General statutes of 1913, are hereby legalized and made of the same force and effect as though the same had been done within said three-year limit. Provided that nothing herein contained shall be construed as affecting any vested rights or any action or proceeding now pending.

GENERAL STATUTES, CHAPTER 105

Sec. 2. Section 1 of Laws of 1917, amended to read as follows: "Sec. 1. There is hereby created a commission to be known as the state securities commission, hereafter referred to as the "commission," whose duty it shall be to administer and provide for the enforcement of all the provisions of this act..

Sec. 3. Section 2 of Laws of 1917, amended to read as follows: "Sec. 2. The provisions of this act, except section 10 thereof, shall not apply to (a) securities of the United States or any foreign government. (b)

....

(d) securities of..........................co-operative associations organized under sections 6479 to 6490 inclusive, general statutes, 1913, for operating creameries, cheese factories, or rural telephone lines, where the authorized capital stock does not exceed twenty-five thousand dollars;...:

Sec. 4. "Investment company" is defined to include coöperative companies except as excluded in Sec. 3.

Sec. 5. Section 4 of Laws of 1917, amended to read as follows: "Sec. 4. No such investment company and no such dealer shall sell or offer for sale any such securities or profess the business of selling or offering for sale such securities, unless and until he or it shall have been licensed by the *commission* as herein provided. To secure such license said investment company or dealer shall file application therefor with the commission and shall furnish said commission, upon oath in form as the commission shall prescribe, the following information, to-wit: The investment company's or dealer's name, residence and business address, the general character of the securities to be sold or dealt in, the place or places where the business is to be conducted within this state, and where the business in this state is not to be conducted by the investment company or by the dealer in person, the names and addresses of all the persons in charge thereof. Said investment company shall pay to the commission a filing fee of one-tenth of one per cent upon the face value of the securities for the sale of which application is made; provided that such filing fee shall not be less than twenty-five dollars.................................

Sec. 10. Provides a penalty of not to exceed $1,000.00, or a year's imprisonment, or both, in case of violation of this act.

IMPORTANT CHANGES IN COÖPERATIVE LAWS

The coöperative law of 1919 modifies that of 1913 in some fundamental respects, and makes a number of important additions to it. The new law follows more closely than the old the fundamental principles of coöperation. Both the old and the new law limit the amount of capital stock that any one person may own to $1,000. Both require that no person shall have more than one vote. But the 1913 law in no way regulates the distribution of earnings. (See Section 6, 485.)

The act passed by the last legislature, however, provides that stock dividends shall not exceed 8 per cent and that the rest of the earnings shall be distributed to members and non-members on the basis of the business done, non-members receiving one half the amount paid to members. The dividends to non-members may be paid in capital stock. (Sec. 7.) It further requires that 10 per cent of the annual net earnings shall be set aside for a reserve fund until this reserve fund shall equal 30 per cent of the paid-up capital stock, and also provides that 5 per cent of the annual net earnings may be used as an educational fund. (Sec. 7.)

The old law adopts the one-man-one-vote principle, but to secure real coöperation, each member of an association must be able to make his vote count, and more important still, be made to feel that he is a real part of the organization. The new law insures this by requiring that notices of all meetings of stockholders shall be published in the newspapers of the principal place of business for two consecutive weeks before the meeting, or that each stockholder shall receive a written notice not less than ten days before the date of such meeting and that the stockholder may then vote by mail in case he is unable to attend the meeting. No one can vote by proxy. (Sec. 3.) Regular meetings of the stockholders shall be held each year at the time specified in the by-laws, and special meetings may be called on petition of 10 per cent of members. (Sec. 4.) A quorum is necessary before any business can be transacted. (See Section 5 for definition of quorum.)

Filing of articles of incorporation.

Law of 1913: (Sec. 6479 and 6487).

Articles of incorporation shall be filed with register of deeds in county of principal place of business, except that associations for the purpose of marketing products of other co-operative associations must file articles of incorporation with the Secretary of State.

Law of 1919: (Sec. 2).

Associations incorporated for $25,000 or less shall file articles of incorporation with register of deeds in the county of principal place of business, but associations incorporated for more than $25,000 shall file articles of incorporation with the Secretary of State, and a certified copy of the same with the register of deeds of the county of its principal place of business.

The new law also gives a detailed statement as to what the articles of incorporation shall contain. (Sec. 2.)

Residence and number of incorporators.

Law of 1913: (Sec. 6479 and 6487).

A majority of the incorporators shall be residents of the county of its principal place of business, except that associations for marketing products of other co-operative associations must have a majority of their incorporators residing in the state.

Law of 1919: (Sec. 2.)

A majority of incorporators shall be residents of the state. Associations with a capitalization of $50,000 or less must have at least 7 incorporators. Associations with a capitalization of more than $50,000 must have at least 15 incorporators.

Limit on capital stock.

Law of 1913: (Sec. 6483 and 6488).

Creameries	$ 25,000
All others	$100,000.

Law of 1919:

The only provision relating to limitation of capital is a section dealing with limitation of promotion expense, found in Sec. 9, which says that associations incorporated for more than $100,000 shall be regulated by the laws of the state regarding the sale of stock by other corporations.

Annual reports.

Law of 1913: (Sec. 6486 and 6488).

Creameries and associations organized for the purpose of marketing products of other cooperative associations shall report to the State Dairy and Food Commissioner. All other associations organized under this act shall report to the Department of Agriculture.

Liability of officers.

Section 6486 of the law of 1913 is not repealed or any part of it changed, but the new law states as additional grounds for dissolution that if any association twice declares a stock dividend in excess of 8 per cent, the Secretary of State may institute proceedings for the forfeiture of its charter. (Sec. 7.)

Provision for purchase of going business.

See section 8 of new law. The law of 1913 does not contain any similar provisions.

Limitation of promotion expense.

Found in new law only. (See Sec. 9.) Limited to 5 per cent of capital stock, except that associations operating in more than one county and with a capital stock of more than $50,000 and less than $100,000 may charge 10 per cent. Associations incorporated for more than $100,000 shall be regulated by laws regarding the sale of stock of other corporations.

Provision for amendment.

The law of 1913, Sec. 6483 states that any association may amend its certificate of incorporation at any general stockholders' meeting called for the purpose, upon ten days' notice to the stockholders.

The law of 1919, Sec. 12, gives many additional details as to amendment to articles of incorporation, but does not repeal the above.

Review by State Securities Commission.

The law of 1917, Chapter 429, Sec. 2, required coöperative companies selling shares of stock to obtain a license from the State Securities Commission, except in the case of creameries, cheese factories, and rural telephone companies with less than $15,000 of authorized capital stock.

The law of 1919, Chapter 105, Sec. 3, raises the exemption for these same companies to $25,000.

Use of name "Coöperative."

The new law prohibits companies hereafter organizing from using the word "coöperative" in the name of the company unless they comply with the provisions of the new act.

APPLICATION OF COÖPERATIVE LAWS

All coöperative companies organized under the statutes of 1913 will continue to operate under that law, unless they elect to come under the provisions of the statute of 1919. Coöperative companies organized previous to 1913 and operating under the general corporation laws of the state will continue as heretofore, unless they elect to come under the new statute. All new coöperative companies must organize according to the new statute. The procedure to be followed in case an old company wishes to come under the new law is the same procedure as required for the adoption of amendments. (Sec 11.) Companies now operating under the general corporation laws will find it easier to arrange their income tax exemptions if they will elect to come under the new law.

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AGRICULTURAL EXPERIMENT STATION

CIDER- AND VINEGAR-MAKING QUALITIES OF MINNESOTA APPLES

BY

W. G. BRIERLEY

DIVISION OF HORTICULTURE

UNIVERSITY FARM, ST. PAUL

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SUMMARY

Sweet cider of good quality can be made from the culls of varieties of apples which are characteristically of good quality.

The "barrel" and the "press-cloth" types of cider presses will produce approximately the same quantity of cider in a given time, but the press-cloth type consumes fewer apples and is generally a superior machine. (See page 12.)

A bushel basket of apples (40 pounds) should yield from 2.5 to 3 gallons of cider, depending upon the variety of apples and the type of press used. (Table II.)

The best quality of sweet cider is obtained from apple varieties which are characteristically of good quality and which have a sweet or pleasant flavor, such as Wealthy, Anisim, Charlamoff, Lowland Raspberry, Whitney (No. 20), Okabena, and Talman (Sweet). Other varieties of value are Antonovka, Northwestern (Greening), Cross, University, and Swaar. (Table II.)

Apples produced in Minnesota yield ciders in which the percentage of total sugars is relatively low. In these investigations the average total sugar content for all the ciders analyzed was found to be 8.01 per cent, while the average total sugar content for cider from apples grown in the eastern states is 10.73 per cent. (See page 21.)

Altho the sugar content is relatively low, good vinegar can be secured from cider made from varieties grown in Minnesota if the fermentation is carefully managed and varieties are used which are known to be dependable for vinegar making, such as Wealthy, Anisim, and Hibernal. (See page 25.)

The vinegar-making possibilities of a variety cider depend upon the behavior of the cider during the fermentation process. A relatively high sugar content in a cider is not a guarantee that vinegar of standard strength can be made from it, for example, Whitney (No. 20) cider, with a sugar content above the average for varieties grown in Minnesota does not make a marketable vinegar. (See pages 24 and 27.)

The behavior of a variety in cider and vinegar making is apparently as characteristic of the variety and fully as constant as are fruit characters, such as size, color, shape, or season.

Vinegars with an acetic acid content of 4 per cent or more can be secured under properly regulated conditions in cask fermentation in six months or less, if varieties are used which have vinegar-making possibilities. The best varieties for vinegar making are Wealthy, Hibernal, and Anisim. Others of value are Charlamoff, Maiden Blush, Utter (Red), Wolf River, Swaar, Talman (Sweet), Okabena, and Cross. (See page 25.)

Vinegars which have not developed satisfactory percentages of acetic acid in six months generally will not develop further and often will lose strength. Such vinegars invariably are obtained from varieties which are poor in vinegar-making qualities, such as Duchess (Oldenburg), Whitney (No. 20), Longfield, and Patten (Greening). (See page 25.)

Cider can be made with a hand press at a cost varying from 16.5 to 24 cents per gallon on the basis of a production of 200 gallons. Selling at 40 cents pays the cost of production of the culls and leaves a profit where otherwise loss would result. Vinegar can be made for approximately the same cost as cider, as the main items of cost are the same in each case, but the slight loss from evaporation and the extra handling of vinegar will add one or two cents per gallon to the cost. The choice of product for sale depends upon varieties available, equipment, and market. (See page 33.)

CIDER- AND VINEGAR-MAKING QUALITIES OF MINNESOTA APPLES

By W. G. BRIERLEY

INTRODUCTION

In seasons when the apple crop in Minnesota has been abundant, observations and reports have led to the conclusion that a considerable part of the fruit was wasted through neglect or through failure to adopt the best practices in marketing. This waste is not so much a loss for the painstaking commercial grower as for the home grower whose orchard is too large for his own needs. Such home orchards are often maintained in a neglected condition or handled indifferently so that the apples produced are not of the best market grade. The common practice in these orchards has been to harvest the numerous varieties hastily, often after the apples have fallen, and to rush them to market to find that buyers are shy or will pay only the lowest prices. Barrels of this sort of fruit may often be seen in the market with an open space of from three to six inches beneath the head, owing to poor condition and a slack pack. Baskets of the same sort of fruit can frequently be found in the market which are in such poor condition that they might properly be condemned as unfit for sale. The fate of such fruit is obvious. Not only is the grower discouraged by his returns, but the whole apple market is disturbed. The commercial grower finds prices depressed and the consumer feels that all apples are to be looked upon with suspicion. Even the careful commercial grower at times has found a part of his fruits below market grade from one cause or another and has been at a loss to know how to dispose of them at a price high enough to meet the cost of production.

Because of this situation it seemed desirable to determine the value of Minnesota apple varieties for cider and vinegar.

The making of cider and vinegar has long been regarded as a profitable way in which to dispose of apples of low grade, but no evidence has been available to show that cider and vinegar of marketable quality can or can not be made from apple varieties commonly grown in this state. So many inquiries were received that a study of this problem was outlined as the best means of securing dependable data and work was begun in the fall of 1914. The Division of Horticulture carried on the work of pressing and fermentation. The

Division of Agricultural Biochemistry analyzed samples of the ciders at the time of pressing and from time to time during the fermentation process.

The studies begun in 1914 were continued throughout the seasons of 1915 and 1916, final data being secured during the winter and spring of 1916-17. The common cask fermentation or so-called "slow process" was followed with the intention of duplicating farm conditions as nearly as possible. The main effort in the work was to determine the value of the several varieties and their behavior in cask fermentation.

PLAN OF THE EXPERIMENTS

The manufacture of cider and cider vinegar has been the object of study for so long, and the technic of the process is so well determined, that it was not considered necessary to study the method of manufacture in the work at this station. In planning this work the intention was to use the common methods under a close approximation of farm conditions in order to determine the value for cider and cider vinegar of the varieties of apples commonly grown in Minnesota. With this general plan in mind the main efforts were confined to the following studies:

1. The effectiveness of hand mills or presses.
2. The yield, quality, and composition of cider from apple varieties grown in Minnesota.
3. The vinegar-making possibilities of these varieties in the cask method of fermentation.
4. The cost of production of cider and vinegar.

In addition it was considered advisable to include some studies of the effect of adding yeast and vinegar starter. It was not the intention, however, to study the nature of the action in this part of the work, but merely to note the effects on vinegar production in the varieties studied.

FACILITIES AND EQUIPMENT

CELLARS USED

A compartment of a storage cellar beneath the greenhouse was used in 1914-15. There were no heating facilities, and the temperature ranged from 50 to 65 degrees, reaching the lower figure in the winter months. In 1915-16 this cellar was used until about the middle of December, when the casks were transferred to a new and larger cellar. This was used through the rest of the season, and again in 1916-17. A single line of steam pipe made it possible to maintain a temperature in this cellar ranging from 65 to 75 degrees throughout the year. These temperatures are higher than would be found in unheated farm cellars, but the average farm cellar can be heated in severe winter weather to 60 or 65 degrees at little expense with a small air-tight stove, burning rough wood for fuel. For vinegar making this heating is very desirable, as the vinegar will be ready for sale in a much shorter time.

TYPES OF PRESSES USED

Medium sized presses of two types were used. One was the common "barrel" or drum press (Figure 1), in which the pomace is ground into the barrel until it is full. The barrel is then slid under the press, a pressure-head put in, and pressure applied, while a second barrel is filled with pomace. For convenience, the second type has been called the "press-cloth" type (Figure 3). In it "cheeses" of pomace are made in squares of press-cloth and separated by drainage boards (see Figures 4 and 5), copying on a smaller scale the construction of a power press.

CASKS USED

Most of the ciders and vinegars were handled in 10-gallon casks in order to save space and to provide containers proportioned to the quantity of cider obtained from runs of two or three bushels. Several 50-gallon barrels were used when larger quantities of cider were available, and two vats of 200-gallon capacity were used in 1916-17. These were found to be less satisfactory than the barrels as well as more expensive and their use is not recommended.

WATER SUPPLY

Water under good pressure was available at all times. This proved a great convenience in keeping the presses clean, washing the apples, keeping down the dust near the presses, and in keeping the air in the cellars properly moistened so that the casks were generally kept in good condition. An adequate water supply is an essential in cider and vinegar making for the purposes stated above, altho it is not so essential to have the water supplied under pressure as to have it in liberal quantities.

SOURCE OF FRUIT

Apples from the orchard at University Farm were used whenever variety yields were sufficient. This supply was supplemented in each of the three seasons of the work by purchase from the Excelsior Fruit Growers' Association. It was necessary to obtain the entire supply at Excelsior in 1915, owing to a crop failure at University Farm. An additional supply was obtained in 1916-17 from F. I. Harris of La Crescent.

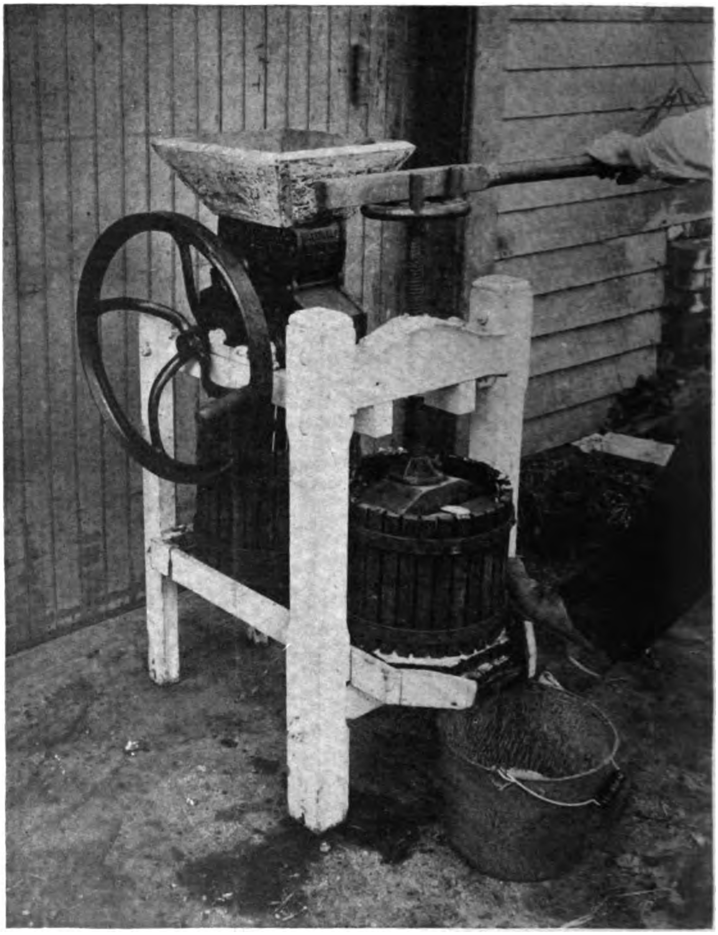

Fig. 1. Barrel Type of Press in Use

METHOD OF HANDLING APPLES AND CIDERS

The only special features of the work were those made necessary in comparing the varieties, such as weighing before pressing, measuring, and making chemical analyses of the ciders when pressed, and analyzing the vinegars from time to time. The apples were first washed and decayed spots were cut out. They were then weighed, ground, and pressed. The cider obtained was measured and strained into the casks or barrels. The time of the whole operation for each run was recorded, the quality of the cider noted, and a sample saved for chemical analysis.

The ciders which were to be used in vinegar studies were handled in accordance with the common method of cask fermentation. The casks or barrels were filled not more than three fourths full; a plug of loose cotton held in a square of cheese-cloth was placed in the bunghole; a starter of compressed yeast was added to the cider; and after the alcoholic fermentation had subsided, the clear liquid was racked off, and a vinegar starter added. Analyses were made from time to time to ascertain the progress of the acetic fermentation and to determine the strength of the vinegar when fermentation was complete.

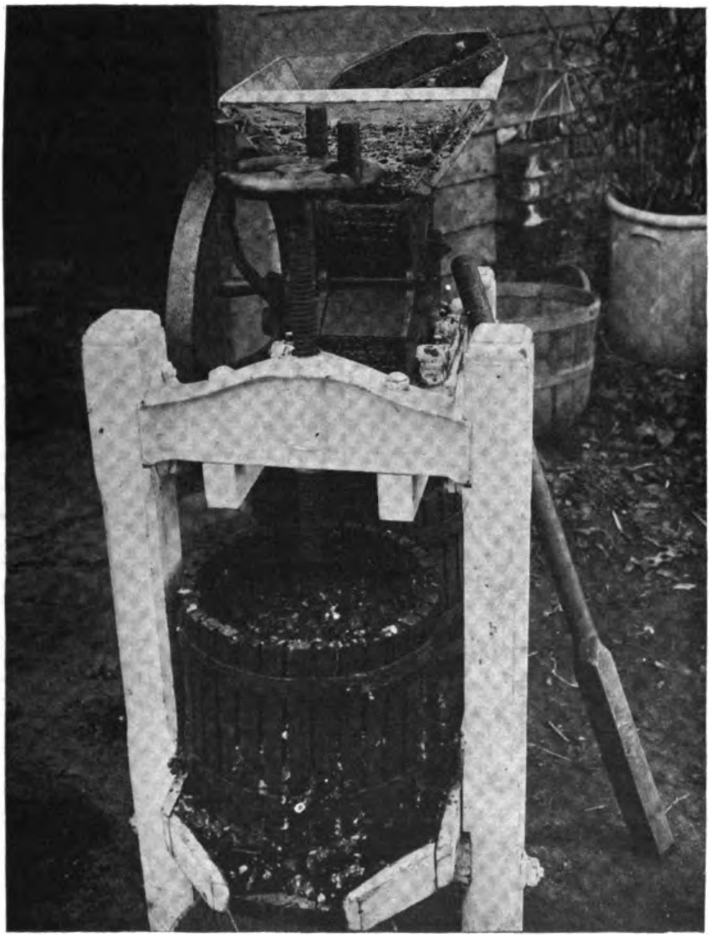

Fig. 2. Barrel Press After Pressing
Note the pomace forced out between the slats of the barrel.

FORTY-POUND BUSHEL WEIGHT ADOPTED

At the beginning of the project it was considered desirable to adopt a standard weight as a basis for the comparison of varieties rather than to use the Minnesota standard bushel basket which has a capacity of 2,150 cubic inches. The weight of bushel measures of Minnesota apples varies somewhat, and comparisons made on the capacity basis consequently would be less accurate. In the opinion of the apple growers of the state the bushel weight should be 40 pounds instead of 50 as prescribed by law. On averaging the weights of more than fifty bushel-basket lots of several common varieties, it was found that 40 pounds was very nearly the average weight. This average was soon determined independently by a committee of the Minnesota State Horticultural Society and later reported to that society.[1]

COMPARISON OF TWO TYPES OF CIDER PRESSES

Two types of cider presses were tested during the course of the work to see if there might be any considerable difference between them in yield of cider from equal weights of apples or in an equal length of time. One was the common barrel or drum press (see Figures 1 and 2) and the other the press-cloth machine (see Figures 3, 4, and 5).

The results of the comparison showed that with the press-cloth type a greater quantity of cider could be made from a given weight of apples, tho the transfer of the pomace from a pail under the grinder to the press-cloths under the press is a little awkward. In the barrel type the pomace falls directly from the grinder into the pressing barrel, and therefore it can be operated a little more rapidly than the press-cloth machine. With the press-cloth machine the pressure can not be left on the pomace while another quantity is being prepared, but judging from the production of cider in a given time (see Table I) this is only a slight disadvantage. In other respects the press-cloth type of machine is clearly superior. In this type of machine the pressure can be made very heavy and the pomace squeezed comparatively dry (see Figure 5), while in the barrel type heavy pressure always results in a disagreeable squirting of the pomace through the slits between the slats of the barrel, and part of the finer pomace oozes out (see Figure 2), making the cider very pulpy.

The pomace in the barrel press is always comparatively wet when pressing is finished and a part of the cider is therefore lost. Several trials showed that when pressed pomace from the barrel press was run through the press-cloth machine, from 50 to 100 per cent of the production from the original pressing in the barrel press was obtained. By placing press-cloths or a clean grain sack in the barrel before grinding the fruit, heavy pressure was applied in this machine and a quantity of cider obtained that nearly equalled that produced by the press-cloth machine. However, as the two machines are generally operated, the advantage of yield from a given quantity of apples is clearly with the press-cloth machine.

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[1] Wright, R. A., Hursch, W. L., and Yanish, E. Minn. State Hort. Soc. Rept. 1915, p. 26.

A comparison of the production of the two types of machines and the effectiveness of one and two operators are shown in Table I. While the actual yield of cider from the two machines was not greatly different, it will be noted that it was necessary to grind a considerably larger quantity of apples and much more labor was required with the barrel machine. Stated otherwise, the press-cloth machine will give as much cider as the barrel press with less labor, and there is not the actual loss of cider due to the lack of efficiency in the barrel press. It will also be seen that the press-cloth machine yielded approximately fifty per cent more from an equal weight of apples than the barrel machine. This superior yield was often exceeded, particularly with very juicy varieties, as with these pressure could not be applied effectively in the barrel press.

In No. 2, a trial of the barrel press, it will be noted that altho the total amount of cider was greater than in No. 1, the comparative loss was approximately sixteen gallons. This amount was actually recovered by re-pressing the pomace in the press-cloth machine.

This table also indicates that with either type of hand-operated machine one man can work with comparatively greater efficiency than two men. In the same time, with the same machines, one man produced approximately three fourths as much cider as two men. As the man working alone did not overexert himself, the conclusion seems safe, altho it might have to be changed for runs extending over a longer time.

TABLE I

COMPARISON OF PRODUCTION OF BARREL AND PRESS-CLOTH MACHINES AND COMPARATIVE EFFECTIVENESS OF ONE AND TWO OPERATORS.*

No.	Type of machine	No. of men	Hours operated	No. of 40-lb. lots	Cider obtained	Average yield per 40 lbs.	Comparative loss per 40 lbs. in barrel press	Total comparative loss in barrel press
					Gallons	Gallons	Gallons	Gallons
1	Press-cloth.....	2	2	10	26.5	2.65	....	.....
2	Barrel..........	2	2	17	29.0	1.71	0.94	15.98
3	Press-cloth.....	1	2	7	21.5	3.07	....	.....
4	Barrel..........	1	2	11	21.0	1.91	1.16	12.76

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* Mixed windfall apples were used.

YIELD AND QUALITY OF CIDERS FROM VARIETIES OF APPLES COMMONLY GROWN IN MINNESOTA

Table II shows the average yield of cider from 40-pound lots of different varieties, the seasons when run, and the number of lots. It was not possible to obtain more than one or two 40-pound lots of some of the varieties in the three seasons in which the work was done. The records for these have been included, however, since they indicate the value of the varieties for cider. The notes on flavor are an indication of the relative sweetness or sourness of the varieties. The aroma, or spiciness, of the ciders is indicated under "Quality." It is taken for granted that the fact is well understood that a cider noted as sweet is acid enough to prevent its being flat or insipid. The notes on both flavor and quality are for ciders pressed from hard-ripe apples except for the four varieties noted in the table.

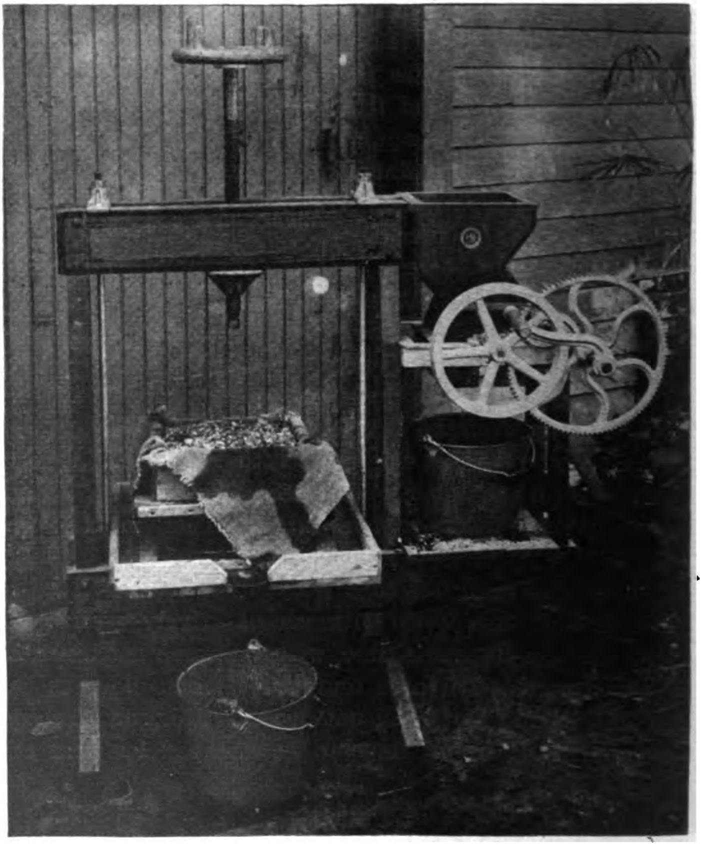

Fig. 3. Press-Cloth Machine Showing How Cloths Are Filled with Pomace

In general, the varieties that are of good quality as eating apples will produce ciders of pleasant flavor and good quality, and those rated as of poor quality for eating generally produce ciders of poor quality. The varieties which invariably produce cider of good quality are: Anisim, Charlamoff, Lowland Raspberry, Okabena, Talman (sweet), Wealthy, Whitney (No. 20). Varieties producing ciders not quite so good as those in the first list, altho they would not be considered poor are: Antonovka, Cross, McMahon, Northwestern (Greening), Peerless, Swaar, University, Utter (Red), and Wolf River. All the other varieties studied produce ciders fair to poor in quality, altho it should be noted that Duchess (Oldenburg),[2] Hibernal, and Patten (Greening), three of the varieties most widely planted in Minnesota, produce ciders which are poor in quality.

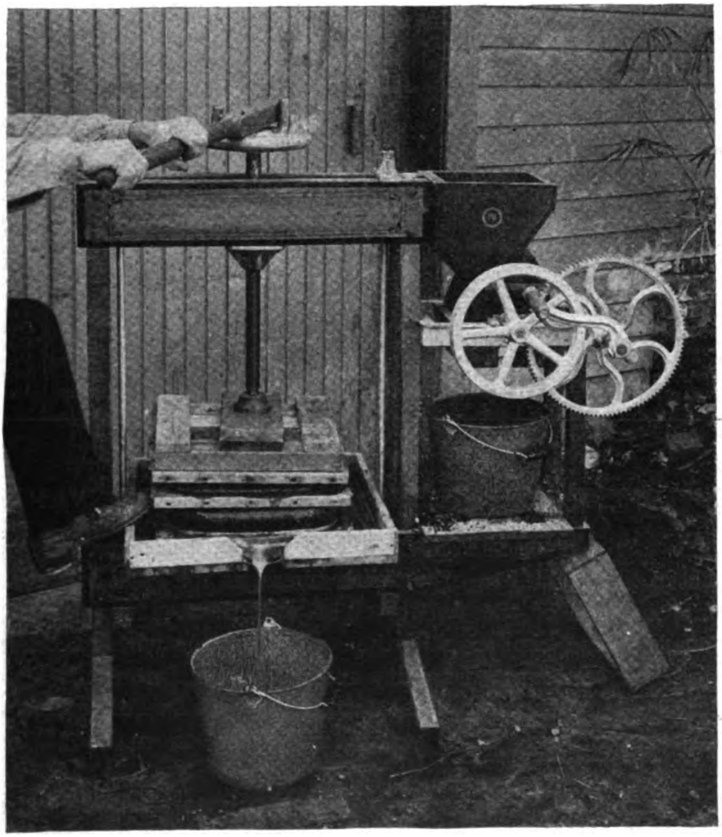

Fig. 4. Press-Cloth Machine Showing Pomace Confined in Press-Cloths Under Heavy Pressure

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[2] This form of the variety name is used, as practically all commercial growers refer to the variety as Duchess.

TABLE II

YIELD, FLAVOR, AND QUALITY OF CIDERS FROM VARIETIES OF APPLES COMMONLY GROWN IN MINNESOTA

Variety	Season run	No. of 40-lb. lots	Average yield	Flavor	Quality
			Gallons		
Anisim	1916	21	2.63	Subacid to sweet	Good to best
Antonovka	1916	3	3.00	Subacid	Good
Charlamoff	1915–16	6	2.75	Sweet	Good to best
Cross	1916	3	3.00	Sweet	Good
Duchess (Oldenburg)	1914–15–16	31	2.75	Very sour	Very poor
Excelsior	1916	1	2.75	Sour	Fair
Florence (Crab)	1915	1*	2.50	Sour and puckery	Very poor
Gilbert	1916	1	2.75	Sour	Fair
Hibernal	1914–15–16	95	3.00	Very sour	Very poor
Longfield	1915–16	8	2.50	Insipid	Very poor
Lowland Raspberry	1915	2*	2.00	Sweet	Good to best
McMahon	1916	3	2.50	Subacid	Fair to good
Maiden Blush	1916	1	3.00	Sour	Poor
Northwestern (Greening)	1916	1	2.75	Sweet	Fair to good
Okabena	1916	2	3.00	Sweet	Good to best
Patten (Greening)	1914–15–16	19	2.88	Sour	Poor
Peerless	1916	1*	2.63	Sweet	Fair to good
Red Wine	1916	1	2.63	Insipid	Poor
Swaar	1916	1	3.00	Sweet	Good
Talman (Sweet)	1916	1	2.50	Sweet	Good to best
University	1916	1	2.75	Sweet	Good
Utter (Red)	1916	1	3.00	Subacid to sweet	Fair to good
Virginia (Crab)	1915	2*	2.25	Sour and puckery	Very poor
Wealthy	1914–15–16	59	2.88	Sweet	Good to best
Whitney (No. 20)	1915–16	6	2.50	Sweet	Good to best
Windfalls	1914–16	118	2.50	Very sour to sweet	Variable
Wolf River	1916	1	2.50	Sweet	Fair to good
Yellow Transparent	1916	1	2.75	Subacid to sweet	Fair

* Soft-ripe.

COMPOSITION OF CIDERS FROM COMMON VARIETIES

The analyses of the ciders made during the three seasons are shown in Table III, together with averages for each variety and a general average of the twenty-eight varieties. The date of pressing, source, and condition of the apples appear with each analysis. While sugar content and acidity are of greatest interest in cider and vinegar making, the analytical data relative to specific gravity, total solids, ash, nitrogen, and starch are given to make the records complete.

For many of the varieties only one or two analyses were completed. This was largely because of the difficulty of obtaining the varieties in quantity. While a single analysis is not a very safe basis for comparisons, it is indicative of the value of the variety. It is of use also in determining the general average for all varieties. Several analyses of each of the varieties studied would have been preferable, but could not be made under existing conditions.

TABLE III

ANALYSES OF CIDERS FROM APPLE VARIETIES COMMONLY GROWN IN MINNESOTA

Variety	Date Pressed	Source	Condition	Specific gravity	Total solids	Reducing sugars	Sucrose	Total sugars	Ash	Acidity as malic	Total nitrogen	Starch
					Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	
Anisim...................	9/14/16	U. Farm	Hard ripe	1.0462	11.63	6.53	2.37	8.9	0.25	0.57	0.016	None
	10/ 3/16	La Crescent	Hard ripe	1.0345	9.22	5.51	2.31	7.82	0.22	0.4	0.0045	None
		Average	....	1.0403	10.42	6.02	2.34	8.36	0.23	0.48	0.0102	None
Antonovka................	9/13/16	Excelsior	Hard ripe	1.0377	9.68	5.49	1.66	7.15	0.23	0.78	0.0155	None
Charlamoff...............	8/30/15	Excelsior	Soft ripe	1.044	8.89	6.96	2.29	9.25	0.19	0.58	0.011	None
	8/30/16	La Crescent	Green	1.032	8.38	5.39	0.0	5.39	0.21	0.25	0.0083	None
	9/ 6/16	Excelsior	Hard ripe	1.0399	11.07	4.75	2.64	7.39	0.25	0.33	0.0087	None
		Average	....	1.0386	9.43	5.7	1.64	7.34	0.21	0.39	0.0093	None
Cross....................	9/13/16	Excelsior	Hard ripe	1.0377	10.28	5.24	2.64	7.88	0.25	0.53	0.0065	None
Duchess (Oldenburg).......	9/ 3/14	U. Farm	Hard ripe	1.024	9.09	5.75	1.68	7.43	0.28	0.77	0.015	Trace
	8/25/15	Excelsior	Hard ripe	1.041	7.59	5.01	2.11	7.12	0.28	1.2	0.012	None
	8/27/15	Excelsior	Soft Ripe	1.047	9.57	6.64	1.96	8.6	0.2	1.1	0.013	None
	8/18/16	U. Farm	Green	1.034	9.77	6.06	1.63	7.69	0.25	0.89	0.02	None
	8/23/16	La Crescent	Hard ripe	1.035	9.08	5.74	1.33	7.07	0.24	0.67	0.01	None
	8/23/16	U. Farm	Hard ripe	1.036	9.76	5.9	1.54	7.44	0.23	0.8	0.028	None
	9/ 5/16	U. Farm*	Soft ripe	1.033	9.06	5.55	1.07	6.62	0.26	0.61	0.02	None
	10/13/16	U. Farm†	Soft ripe	1.040	9.2	6.67	1.59	8.26	0.19	0.36	0.012	None
		Average		1.036	9.14	5.91+	1.61+	7.53	0.24	0.8	0.016	None
Excelsior................	9/ 7/16	Excelsior	Hard ripe	1.045	10.84	5.26	2.41	7.67	0.24	0.52	0.0298	None
Florence (Crab)...........	9/ 1/15	Excelsior	Soft ripe	1.040	8.31	6.1	2.44	8.54	0.21	0.81	0.015	None
Gilbert..................	8/30/16	La Crescent	Hard ripe	1.0348	9.27	5.92	1.48	7.4	0.22	0.43	0.0043	None
Hibernal.................	9/19/14	U. Farm	Hard ripe	1.035	8.9	6.33	1.59	7.92	0.28	1.13	0.008	None
	10/ 1/15	Excelsior	Soft ripe	1.047	9.01	7.4	0.45	7.85	0.33	1.16	0.019	None
	8/25/16	U. Farm	Green	1.034	7.82	5.48	0.83	6.31	0.23	1.12	0.0185	None
	9/14/16	U. Farm	Hard ripe	1.0433	10.15	6.79	2.27	9.06	0.26	0.95	0.0215	None
	9/20/16	U. Farm	Hard ripe	1.0412	10.82	6.51	1.89	8.4	0.17	0.69	0.02	None
	10/12/16	U. Farm*	Soft ripe	1.0428	9.05	6.78	0.83	7.61	0.25	0.72	0.026	None
	10/18/16	La Crescent	Hard ripe	1.044	9.32	5.87	1.66	7.53	0.23	0.54	0.01	None
	12/ 5/16	U. Farm†	Soft ripe	1.0455	10.65	6.79	1.26	8.05	0.26	1.08	0.021	None
		Average	....	1.0416	9.46	6.49+	1.34+	7.84+	0.25	0.92	0.018	None

* Cellar storage.
† Cold storage.

TABLE III—*Continued*

ANALYSES OF CIDERS FROM APPLE VARIETIES COMMONLY GROWN IN MINNESOTA

Variety	Date pressed	Source	Condition	Specific gravity	Total solids	Reducing sugars	Sucrose	Total sugars	Ash	Acidity as malic	Total nitrogen	Starch
					Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	
Longfield	9/16/15	Excelsior	Hard ripe	1.039	9.65	6.57	0.6	7.17	0.22	0.82	0.014	None
	9/28/15	Excelsior	Soft ripe	1.048	10.16	6.35	0.75	7.1	0.26	1.16	0.021	None
	10/17/16	La Crescent	Hard ripe	1.0394	7.86	5.67	1.89	7.56	0.18	0.29	0.004	None
		Average	....	1.0421	9.22	6.19+	1.08	7.28	0.22	0.75	0.013	None
Lowland Raspberry	8/26/15	Excelsior	Soft ripe	1.049	8.36	4.42	3.24	7.66	0.24	0.52	0.014	None
McMahon	10/10/16	La Crescent	Hard ripe	1.0389	9.33	6.28	1.24	7.52	0.21	0.32	0.0073	None
	10/31/16	Excelsior	Soft ripe	1.0494	11.24	5.96	3.32	9.28	0.21	0.58	0.017	None
		Average	....	1.0441	10.28	6.12	2.28	8.4	0.21	0.45	0.0121	None
Maiden Blush	10/ 2/16	La Crescent	Hard ripe	1.036	9.4	5.32	2.19	7.51	0.23	0.53	0.0055	None
Northwestern (Greening)	10/17/16	La Crescent	Hard ripe	1.042	9.59	6.77	1.28	8.05	0.21	0.24	0.0092	None
Okabena	9/19/16	Excelsior	Hard ripe	1.044	11.34	5.23	3.92	9.15	0.21	0.55	0.0095	None
Patten (Greening)	9/19/14	U. Farm	Hard ripe	1.034	8.56	5.94	2.03	7.97	0.22	0.86	0.022	Trace
	9/16/15	Excelsior	Hard ripe	1.044	10.2	6.87	0.91	7.78	0.34	1.01	......	None
	10/ 1/15	Excelsior	Soft ripe	1.053	10.43	7.6	0.61	8.21	0.34	1.0	0.024	None
	10/30/15	Excelsior*	Soft ripe	1.048	10.87	7.4	1.0	8.4	0.24	0.9	0.033	None
	8/25/16	U. Farm	Green	1.039	9.81	6.46	1.44	7.9	0.23	0.79	0.02	None
	9/14/16	U. Farm	Hard ripe	1.0363	8.92	5.73	2.11	7.84	0.28	0.63	0.016	None
	9/20/16	U. Farm	Hard ripe	1.045	10.99	5.75	2.79	8.54	0.18	0.7	0.029	Trace
	10/ 3/16	La Crescent	Hard ripe	1.0343	8.93	5.57	2.48	8.05	0.19	0.42	0.004	None
	10/12/16	U. Farm*	Soft ripe	1.0422	9.02	7.02	1.13	8.15	0.22	0.48	0.012	None
	12/ 5/16	U. Farm†	Soft ripe	1.0399	9.25	6.15	0.75	6.9	0.27	0.81	0.014	None
		Average	....	1.0416	9.7	6.45	1.52	7.97	0.25	0.76	0.0174	None
Peerless	10/ 2/16	La Crescent	Soft ripe	1.042	10.54	5.73	3.0	8.73	0.26	0.47	0.006	None
Red Wine	8/23/16	La Crescent	Hard ripe	1.024	6.17	4.82	0.62	5.44	0.22	0.34	0.0063	None
Swaar	10/ 3/16	La Crescent	Hard ripe	1.0393	9.62	5.57	3.34	8.91	0.2	0.38	0.0049	None
Talman (Sweet)	10/17/16	La Crescent	Hard ripe	1.0516	11.87	7.26	3.17	10.43	0.21	0.07	0.01	None
University	10/18/16	La Crescent	Hard ripe	1.0388	8.6	6.07	1.28	7.35	0.14	0.29	0.0065	None
Utter (Red)	10/ 3/16	La Crescent	Hard ripe	1.0337	9.41	6.17	1.81	7.98	0.18	0.27	0.002	None
Virginia (Crab)	9/ 7/15	Excelsior	Soft ripe	1.055	11.46	6.8	1.9	8.7	0.43	0.9	0.018	None

* Cellar storage.
† Cold storage

TABLE III—*Continued*

ANALYSES OF CIDERS FROM APPLE VARIETIES COMMONLY GROWN IN MINNESOTA

Variety	Date pressed	Source	Condition	Specific gravity	Total solids	Reducing sugars	Sucrose	Total sugars	Ash	Acidity as malic	Total nitrogen	Starch
					Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	
Wealthy..................	10/ 1/14	U. Farm	Soft ripe	1.0227	7.54	5.98	1.64	7.62	0.28	0.61	......	None
	10/ 1/14	U. Farm	Soft ripe	1.0236	7.66	6.01	1.64	7.65	0.27	0.6	......	None
	9/16/15	Excelsior	Hard ripe	1.045	9.87	7.45	1.36	8.81	0.2	0.8	0.01	None
	9/28/15	Excelsior	Soft ripe	1.047	10.61	6.8	0.45	7.25	0.19	0.87	0.016	None
	10/30/15	Excelsior*	Soft ripe	1.044	9.81	7.99	0.4	8.39	0.22	0.65	0.015	None
	10/30/15	Excelsior*	Soft ripe	1.046	10.43	8.38	0.69	9.07	0.21	0.69	0.018	None
	8/18/16	U. Farm	Very green	1.028	8.19	6.03	0.42	6.45	0.23	0.76	0.0195	None
	8/30/16	U. Farm	Green	1.039	9.27	7.26	0.95	8.21	0.23	0.34	0.0081	None
	9/14/16	U. Farm	Hard ripe	1.0374	10.34	6.49	1.96	8.45	0.21	0.58	0.0055	None
	9/18/16	Excelsior	Hard ripe	1.039	10.01	5.74	1.69	7.43	0.21	0.59	0.0058	None
	10/ 2/16	U. Farm	Hard ripe	1.042	9.51	7.17	1.7	8.87	0.21	0.44	0.0011	None
	10/10/16	La Crescent	Hard ripe	1.0389	8.18	5.6	0.91	6.51	0.18	0.27	0.0062	None
	10/12/16	U. Farm*	Soft ripe	1.0408	9.5	7.18	0.98	8.16	0.18	0.37	0.017	None
	12/ 5/16	U. Farm†	Soft ripe	1.041	9.06	6.28	0.97	7.25	0.17	0.59	0.012	None
		Average	....	1.0381	9.28	6.74	1.12+	7.86+	0.21	0.58	0.0111	None
Whitney (No. 20)..........	8/27/15	Excelsior	Soft ripe	1.048	10.85	6.22	2.86	9.08	0.31	0.55	0.015	None
	9/ 5/16	Excelsior	Hard ripe	1.0437	11.57	6.74	2.17	8.91	0.3	0.33	0.024	None
		Average	....	1.0458	11.21	6.48	2.515	8.995	0.3	0.44	0.019	None
Wolf River................	10/18/16	La Crescent	Hard ripe	1.0479	11.16	6.34	2.72	9.06	0.27	0.37	0.0069	None
Windfalls..................	9/19/14	U. Farm	Hard ripe	1.035	8.52	6.54	1.38	7.92	0.28	1.11	0.007	None
(Mixed varieties)	8/21/16	U. Farm	Green and hard ripe	1.0369	8.52	5.78	1.9	7.68	0.26	0.42	0.0205	None
		Average	....	1.036	8.52	6.16	1.64	7.8	0.27	0.77	0.0137	None
Yellow Transparent.........	8/25/16	Excelsior	Hard ripe	1.039	9.37	5.63	1.66	7.29	0.17	0.9	0.02	None
Average, 28 varieties......	....	....	....	1.0407	9.71	5.94+	2.06+	8.01	0.23	0.53	0.0116	None

* Cellar storage.
† Cold storage

It will be noted in this table that the ciders listed in Table II as of good quality are either relatively high in total sugar content or relatively low in acidity, or both, in comparison with the general average for all varieties. Conversely, the ciders listed as poor in quality in Table II are shown here to be either low in total sugar content or of high acidity, or both. This general relation of sugar and acidity

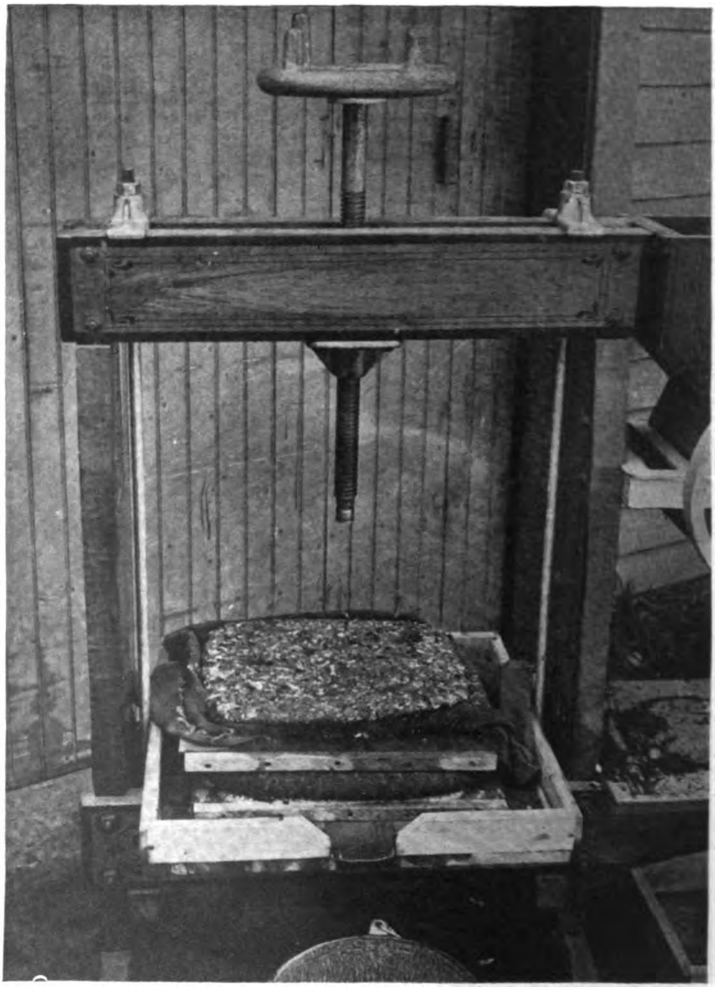

Fig. 5. Press-Cloth Machine After Pressing
Note the hard, dry cake of pomace.

in a measure interprets the statement in regard to quality in Table II, but is of no significance in the vinegar-making quality of a cider. The percentage of total sugars is the item of chief significance in vinegar making, as vinegar is produced by a double fermentation process in which the sugars are first changed into alcohol by the action of yeast, and the alcohol is then changed into acetic acid by the action of bacteria.

Of the twenty-eight varieties analyzed, the sample showing the highest yield in total sugars was Talman (Sweet) (1916) with 10.43 per cent. The lowest was green Charlamoff (1916) with 5.39 per cent. The general average for the three seasons shows 8.01 per cent total sugars. Comparing this sugar content with the average of 10.73 per cent for eastern apples[3], it will be seen that, as a whole, Minnesota ciders are low in total sugar content. In general theory and practice it is necessary to have at least 8 per cent of total sugar in a cider to secure a vinegar of 4 per cent acetic acid, which is the legal standard in Minnesota. From the foregoing it appears that for vinegar making the varieties should generally be selected on the basis of a sugar content equal to or above the average, and that the best conditions for fermentation should be secured. However, as shown later in the discussion of the vinegar-making qualities of the several varieties (page 24), the sugar content is not always an indication of the possibilities of a variety for vinegar making, but it is evident that if a cider generally tends to run low in sugar content it will be of little value for vinegar making.

SUGAR CONTENT OF CIDERS FROM APPLES AT DIFFERENT STAGES OF MATURITY

While it has been assumed on the basis of analyses of eastern ciders[4] that the sugar content of ciders made from Minnesota apples will increase with maturity and decrease as the apples become over-ripe, it is of interest to note how well four varieties of apples commonly grown in this state follow this general rule. In Table IV it will be noted that Wealthy might readily serve as a model for the general rule, so regular is the increase and decrease in the percentage of total sugar. Patten (Greening) is a little less regular, while Hibernal and Duchess (Oldenburg) show rather marked irregularities. However, in general the sugars are present in greatest quantity when the apples are "hard ripe." This, then, is obviously the best stage of fruit maturity for cider and vinegar making.

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[3] Van Slyke, L. L. "A study of the chemistry of home-made cider vinegar" N. Y. State Exp. Sta. (Geneva) Bull. 258, p. 449, Table III. Reducing sugars 7.28 + Sucrose 3.45 = 10.73 Total sugars. 1904.

[4] Browne, C. A., Jr. "A chemical study of the apple and its products." Penn. Dept. Agr. Bull. 58, p. 14, Table III. 1899.

TABLE IV

SUGAR CONTENT OF CIDERS FROM APPLES AT DIFFERENT STAGES OF MATURITY*
(Complete analyses given in Table III under same dates.)

Variety	Date	Condition	How handled	Reducing sugars	Sucrose	Total sugars
				Per cent	Per cent	Per cent
Wealthy.......	8/18/16	Very green	Pressed immediately	6.03	0.42	6.45
	8/30/16	Green	Pressed immediately	7.26	0.95	8.21
	9/14/16	Hard ripe	Pressed immediately	6.49	1.96	8.45
	10/2/16	Hard ripe	Pressed immediately	7.17	1.70	8.87
	10/12/16	Soft ripe	Cellar storage, 4 weeks	7.18	0.98	8.16
	12/5/16	Soft ripe	Cold storage, 12 weeks	6.28	0.97	7.25
Hibernal.......	8/25/16	Green	Pressed immediately	5.48	0.83	6.31
	9/14/16	Hard ripe	Pressed immediately	6.79	2.27	9.06
	9/20/16	Hard ripe	Pressed immediately	6.51	1.89	8.4
	10/12/16	Soft ripe	Cellar storage, 4 weeks	6.28	0.97	7.25
	12/5/16	Soft ripe	Cold storage, 12 weeks	6.79	1.26	8.05
Patten......... (Greening)	8/25/16	Green	Pressed immediately	6.46	1.44	7.9
	9/14/16	Hard ripe	Pressed immediately	5.73	2.11	7.84
	9/20/16	Hard ripe	Pressed immediately	5.75	2.79	8.54
	10/12/16	Soft ripe	Cellar storage, 4 weeks	7.02	1.13	8.15
	12/5/16	Soft ripe	Cold storage, 12 weeks	6.15	0.75	6.9
Duchess........ (Oldenburg)	8/18/16	Green	Pressed immediately	6.06	1.63	7.69
	8/23/16	Hard ripe	Pressed immediately	5.9	1.54	7.44
	9/5/16	Soft ripe	Cellar storage, 2 weeks	5.55	1.07	6.62
	10/13/16	Soft ripe	Cold storage, 7 weeks	6.67	1.59	8.26

* All apples were grown at University Farm.

VINEGAR-MAKING QUALITY OF CIDERS FROM VARIETIES COMMONLY GROWN IN MINNESOTA

The vinegar-making possibilities of the ciders obtained from varieties commonly grown in Minnesota are shown in Table V. Under each variety is recorded the year fermented, the number of months from the date of pressing to the time when the acetic acid reached the highest percentage, and remarks relating to the behavior of any individual cask. A summary or average is given for each variety, showing the average acetic acid strength, the comparative quality of the variety vinegar, the average percentage of total sugars found in the sweet cider (Table III) for purposes of comparison, and the value of the variety for vinegar-making.

VINEGAR-MAKING QUALITY A VARIETY CHARACTER

The more common varieties, such as Anisim, Duchess (Oldenburg), Hibernal, Patten (Greening), and Wealthy, furnished the opportunity for fairly extensive studies, and the results can be regarded as clearly indicating the value of these varieties in the cask method of vinegar manufacture. The other varieties could not be obtained in sufficient quantity for extensive studies, but at least one cask of each variety was carried through the fermentation process with results as noted. Where these single-cask fermentation trials resulted in a vinegar well above 4 per cent of acetic acid, for example that made from Cross, Okabena, Swaar, Talman (Sweet), Utter (Red), and Wolf River; or below 2 per cent of acetic acid, that made from Excelsior, Florence (Crab), Red Wine, and Whitney (No. 20), it is not likely that more extensive fermentation studies would materially affect the results as stated, as all the ciders were given identical treatment. With those varieties which developed a vinegar containing slightly less than 4 per cent of acetic acid, there is a possibility that more extensive trials would affect to a slight extent the results given in Table V owing to the variations which are to be expected in cask fermentation. However, it has been noticed in these studies that a cider, for example Wealthy, which is considered capable of developing into a vinegar of standard strength generally will develop into such a vinegar under average fermentation conditions. On the other hand a cider, for example Duchess (Oldenburg), which is considered not capable of developing into a vinegar of standard strength, generally will not produce a marketable vinegar, even under the most favorable circumstances. The writer is of the opinion that this behavior is a variety character which is as constant as fruit characters such as color, size, shape, or season.

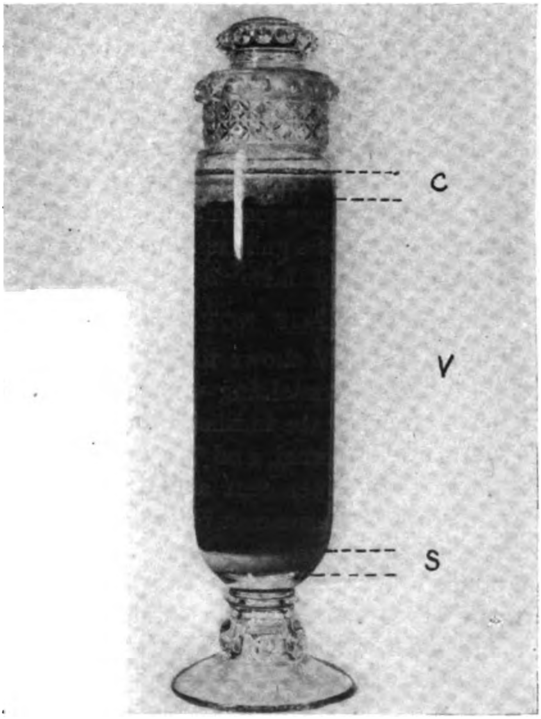

Fig. 6. Jar of Vinegar, Fermented with Cover Removed, not "Racked"
The clear vinegar is shown at V; cake, at C, and sediment at S.

VARIATIONS IN FERMENTATION RATIO

Attention is called to the fact that these variety ciders often do not follow even in a general way the commonly accepted fermentation ratio for the production of acetic acid. It is generally expected that 8 per cent or more of total sugars will by fermentation yield 4 per cent or more of alcohol, from which in turn approximately 4 per cent of acetic acid will be obtained. Marked departures from this ratio are readily seen in Table V. Wealthy cider, averaging 7.86+ per cent total sugars, produced vinegar averaging 4.54 per cent acetic acid, an excess of 0.61 per cent above the ratio. In one instance Wealthy cider containing 8.87 per cent total sugars produced, instead of approximately 4.44 per cent acetic acid, according to the ratio, 6.24 per cent, or an excess of nearly one-half. Whitney (No. 20) cider showed the opposite behavior, as from a total sugar content of 8.99 per cent, less than 2 per cent of acetic acid developed. Other marked departures from the ratio may be readily noted. No attempt was made to determine the cause or causes for this variation. In a study of the vinegar-making possibilities of variety ciders in cask fermentation the chief significance of this fact is that it shows more markedly the varietal behavior of ciders in fermentation.

LONG STORAGE NOT NECESSARY

Further study of Table V shows that varieties capable of yielding a marketable vinegar containing 4 per cent or more of acetic acid generally have produced the finished product in about six months from pressing. Anisim, Hibernal, and Wealthy ciders each produced vinegars with more than 4 per cent acetic acid in two and a half months. It seems from performances of this sort that it is not at all necessary to let vinegars stand for a long time in order to produce a marketable product. On the other hand, the varieties which apparently are of little or no value for vinegar making, such as Duchess (Oldenburg), Longfield, or Patten (Greening), not only did not reach an acetic acid strength of 4 per cent but actually lost strength after a few months. As all the casks were handled in the same cellar under uniform conditions it seems that there is nothing to be gained by keeping the poor varieties a long time, altho this is contrary to experience elsewhere, particularly in New York.[5] This difference very probably may be due to the difference in varieties and to the lower sugar content of Minnesota apples. Any reliable variety cider left in a cold cellar doubtless will require a longer time to develop full strength as vinegar than when left in a warm cellar, but if kept at a temperature of 65 to 75 degrees, Fahrenheit, marketable vinegar can unquestionably be made in a few months and the slight cost of heating the cellar will be more than met by the rapidity with which the vinegar is finished. Temperatures ranging somewhat above 75 degrees will still further accelerate the fermentation, but more fuel will be needed and there will be a slightly greater loss from evaporation. The marked advantages of rapid fermentation are that casks need not be stored from two to four years in order to produce a marketable vinegar, that the same cellar space and casks may be used each season, and that returns on the investment can be expected in a reasonably short time after pressing the cider.

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[5] Van Slyke, L. L. "A study of the chemistry of home-made cider vinegar." N. Y. Exp. Sta. (Geneva). Bull. 258, p. 456, Table VIII. 1904.

VARIETIES RECOMMENDED

Varieties that may be considered dependable for vinegar making are: Anisim, Charlamoff, Cross, Hibernal, McMahon, Maiden Blush, Okabena, Swaar, Talman (Sweet), Utter (Red), Virginia (Crab), Wealthy, and Wolf River. All of these varieties used separately or in a mixture, should produce vinegar of standard strength if the few simple rules are followed for cask fermentation. Varieties which apparently have no value for vinegar manufacture are: Duchess (Oldenburg), Excelsior, Florence (Crab), Longfield, Red Wine, and Whitney (No. 20). Patten (Greening) probably should also be included in this list, altho vinegar of fair quality was produced from this variety in 1915-16. The remaining varieties are of doubtful value, altho Antonovka, Gilbert, University, and Yellow Transparent produced vinegars of fair quality and of more than 3 per cent acetic acid. In general, the best procedure will be to use only dependable varieties so that useless expenditure of time and labor may be avoided.

Attention is called to the widely varying results secured from windfall apples. When windfalls are mixed indiscriminately the good and poor varieties each have their proportionate effect upon the resulting cider and vinegar. If there is a preponderance of good varieties a good grade of vinegar may be obtained, but the best practice is to eliminate all windfalls of the varieties listed as having no value in vinegar making.

TABLE V

VINEGAR-MAKING RECORDS OF CIDERS FROM VARIETIES COMMONLY GROWN IN MINNESOTA[*]

Variety	Year	Months fermenting	Total sugar	Acetic acid	Quality	Remarks
			Per cent	Per cent		
Anisim.......	1916	6	....	4.08		
	1916	6	....	4.14		
	1916	6	....	4.96	....	Acetic acid at 2½ months was 4.2 per cent
	1916	6	....	4.63		
Average....	....	..	8.36	4.45	Good to best	One of the best for vinegar making.
Antonovka...	1916	6	7.15	3.56	Fair	Suitable for home use.
Charlamoff...	1915	12	....	3.18		
	1916	6	....	4.94		
Average....	....	..	7.34	4.06	Good to best	Probably dependable.
Cross........	1916	6	7.88	4.3	Good to best	One of the best for vinegar making.
Duchess...... (Oldenburg)	1915	10	....	1.91		
	1916	7	....	2.27	....	All of these lost strength after seven months.
	1916	7	....	0.59		
	1916	7	....	1.69		
	1916	7	....	1.85		
	1916	7	....	0.41		
Average....	....	....	7.53	1.39	Worthless	Of no value for vinegar making.
Excelsior.....	1916	6	7.67	0.23	Worthless	Of no value for vinegar making.
Florence..... (Crab)	1915	6	8.54	1.44	Worthless	Lost strength after 6 months.
Gilbert.......	1916	6	7.4	3.27	Fair	Suitable for home use.
Hibernal.....	1915	12	....	4.67		
	1916	6	....	4.34		
	1916	6	....	6.42		
	1916	6	....	5.82	....	Acetic acid at 2½ months was 4.43 per cent.
	1916	6	....	6.22		
	1916	9	....	4.5	....	Fermented in upright barrel with open end.
	1916	9	....	3.27	....	Fermented in 200-gallon covered vat.
Average....	....	....	7.84	5.03	Good to best	One of the best for vinegar making.
Longfield.....	1915	8	....	2.04	....	Lost strength rapidly.
	1915	6	....	2.9	....	Lost strength after six months.
	1915	10	....	0.77	....	Lost strength after 10 months.
Average....	....	....	7.28	1.9	Worthless	Of no value for vinegar making.
McMahon....	1916	6	8.4	3.9	Good	Probably dependable for vinegar making. Cask damaged after six months and vinegar lost.
Maiden Blush.	1916	5	7.51	4.25	Good	Very good for vinegar making.
Northwestern. (Greening)	1916	5	8.05	2.74	Poor	Lost strength after five months.
Okabena.....	1916	6	9.15	5.28	Good to best	One of the best for vinegar making.
Patten....... (Greening)	1915	6	....	3.76	....	Lost strength slowly after six months.
	1915	6	....	4.12	....	Lost strength slowly after six months.
	1916	3	....	0.64		
	1916	3	....	0.59		
	1916	3	....	0.48	....	Subsequent analyses showed loss of acetic acid.
	1916	6	....	0.6		
Average....	....	....	7.97	1.7	Worthless to fair	Promised well in 1915. Probably not dependable.

[*] All records are for cask fermentation.

TABLE V—*Continued*

VINEGAR-MAKING RECORDS OF CIDERS FROM VARIETIES COMMONLY GROWN IN MINNESOTA*

Variety	Year	Months fermenting	Total sugar	Acetic acid	Quality	Remarks
			Per cent	Per cent		
Peerless......	1916	5	8.73	2.48	Very poor	Lost strength after five months.
Red Wine....	1916	6	5.44	1.5	Worthless	Lost strength after six months.
Swaar.......	1916	5	8.91	5.56	Good to best	One of the best for vinegar making.
Talman...... (Sweet)	1916	5	10.43	4.7	Good to best	One of the best for vinegar making.
University....	1916	5	7.35	3.46	Fair	Suitable for home use. Lost strength after five months.
Utter (Red)..	1916	5	7.98	4.11	Good to best	Very good for vinegar making.
Virginia (Crab)	1915	5	8.7	4.83	Good	Good.
Wealthy.....	1915	5	....	5.08	....	Acetic acid increased to 6.18 per cent by twelfth month.
	1915	5	....	4.63		
	1916	6	....	5.0		
	1916	6	....	4.58		
	1916	6	....	4.81		
	1916	6	....	4.64		
	1916	5	....	6.24	....	Acetic acid at 2½ months was 6.22 per cent.
	1916	5	....	4.17		
	1916	5	....	3.69		
	1916	5	....	4.33		
	1916	5	....	4.36		
	1916	5	....	4.73	....	Acetic acid at 2½ months was 4.19.
	1916	6	....	3.4	....	Made from green apples.
	1916	5	....	3.95	....	Cider temporarily preserved with benzoate of soda.
Average....	....	....	7.86+	4.54	Good to best	One of the best for vinegar making.
Whitney.....	1915	6	....	2.4		
(No. 20)	1916	9	....	1.0	....	Lost strength after six months.
Average....	....	....	8.99	1.7	Worthless	Of no value for vinegar making.
Wolf River...	1916	5	9.06	4.99	Good to best	One of the best for vinegar making.
Windfalls....	1914	18	....	2.83		
(Mixed	1916	5	....	4.27		
varieties)	1916	9	....	0.38		
	1916	6	....	0.41		
	1916	9	....	3.97		
	1916	9	....	1.16	....	Fermented in 200-gallon covered vat.
	1916	9	....	3.46		
	1916	9	....	2.0	....	Fermented in upright barrel with open end.
	1916	9	....	1.58		
Average....	....	....	7.80	2.23	Variable	Strength and quality depend on varieties in mixture.
Yellow Transparent.....	1916	6	7.29	3.56	Fair	Lost strength after six months.

* All records are for cask fermentation.

EFFECTS OF MODIFICATIONS IN FERMENTATION METHOD ON STRENGTH OF VINEGAR

Simple modifications of the usual method of handling ciders during fermentation were undertaken as a further test of variety behavior. The purpose of this study was to determine if such modifications would in any way cause a variation in the resulting strength as compared to the normal behavior. It was planned to divide uniform variety ciders into four lots, all to be held in the same cellar so that any fluctuations in temperature would affect all alike. Two of these lots were to have yeast added immediately, and at the end of the alcoholic fermentation vinegar "starter" was to be added to one of these yeast casks and also to one of the two without yeast. In this way the four combinations of the yeast and starter factors would be secured. In all other respects the common method for cask fermentation was followed.

RESULTS IN 1915-1916

In 1915-16 uniform cider from Wealthy apples was divided into four lots of 7.5 gallons each in 10-gallon casks. Yeast was added to two of these casks at the rate of one cake to five gallons of cider. Difficulty was experienced in obtaining a satisfactory vinegar starter, so that part of the study had to be deferred. Also, one of the casks without yeast proved defective and the greater part of the cider was lost. Accordingly the work resolved itself into a study of the effect of yeast on vinegar strength. Analyses made five months after pressing showed the following results:

TABLE VI

EFFECT OF ADDITION OF YEAST ON STRENGTH OF WEALTHY VINEGAR*

Treatment	Percentage acetic acid	Percentage alcohol
Yeast added	5.08	0.76
No yeast	4.63	2.37

* Cider pressed September 29, 1915, vinegars analyzed March 4, 1916. Total Sugar Content 7.25 per cent.

Considering the figures given in Table VI for acetic acid, it would seem that the addition of yeast was beneficial. However, the direct effect of yeast in fermentation is the production of alcohol from which the acetic acid is derived later in nearly equal volume. With this point in mind it will be seen that this Wealthy cider produced more acetic acid, plus alcohol, without the addition of yeast, or through natural fermentation. Cellar conditions made it impossible to continue the work with these casks, but without doubt much of the alcohol in the cask to which no yeast was added would have formed acetic acid later and thus have made the vinegar in this cask at least equal in strength to that in the yeast cask. The only evident benefit derived from the addition of yeast in this comparison is that a stronger vinegar was formed in the same length of time. This greater strength might easily be caused by the variation in cask behavior[6] and as the cask with no yeast produced a vinegar of excellent market quality, it is doubtful if the addition of yeast was of any real benefit.

RESULTS IN 1916-1917

These studies were continued in 1916-17 with cider from five varieties of apples, and with much better cellar facilities. Uniform ciders from Wealthy, Duchess (Oldenburg), Hibernal, Patten (Greening), and Anisim were divided into four lots of 7.5 gallons each, put in 10-gallon casks, and kept at a temperature ranging from 55 to 70 degrees Fahrenheit. These four lots of each variety were handled as follows:

Cask No. 1. Compressed yeast added at the rate of one cake to five gallons. After alcoholic fermentation had apparently ceased, one quart of good vinegar added as starter.

Cask No. 2. Yeast added as in No. 1, but no starter.

Cask No. 3. No yeast added, but starter as in No. 1.

Cask No. 4. No yeast, no starter.

Samples from these twenty casks were analyzed for specific gravity and acidity on December 9, 1916, March 8, 1917, and May 31, 1917, except that the third analysis was not made for the casks showing a finished vinegar on March 8. The results for each variety appear in Table VII. These lots showed such variable results that the only conclusions which can be drawn are that a cider from a variety, as Wealthy, which is capable of producing vinegar of standard strength, will do so regardless of modifications in the fermentation procedure, if kept at ordinary room temperature under the usual methods for cask fermentation; and that a cider from a variety, as Duchess (Oldenburg), which under other conditions will not produce a standard vinegar, seemingly can not be made to develop into a standard vinegar by these methods.

Some greater uniformity of results possibly might be obtained in such a study if ciders were properly sterilized immediately after pressing, but this would add considerably to the cost of production and would not be practical under farm conditions. Apparently wild yeasts and bacteria are present in sufficient quantity to insure proper fermentation and the production of marketable vinegars. It is evident from Table VII that the cake yeast and vinegar starter had no appreciable effect on the results in these experiments, altho beneficial action has been reported for similar studies in New York.[7]

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[6] See figures for Wealthy, Table V.

[7] Van Slyke, L. L. "A study of the chemistry of home-made cider vinegar." N. Y. Exp. Sta. (Geneva) Bull. 258, p. 454, Table VII. and p. 460, Table XII. 1904.

TABLE VII
EFFECTS OF MODIFICATIONS IN FERMENTATION METHOD ON THE STRENGTH OF VINEGAR

Duchess (Oldenburg)
Pressed August 26, 1916

Cask No.	Treatment	Dec. 9, 1916		March 8, 1917		May 31, 1917	
		Sp. Gr.	Acidity	Sp. Gr.	Acidity	Sp. Gr.	Acidity
			Per cent		Per cent		Per cent
I	Yeast and starter............	1.0013	1.68	1.0088	2.27	1.0051	1.08
II	Yeast only..................	0.9978	0.51	1.0065	0.59	1.0053	0.07
III	Starter only................	0.9977	0.54	1.0072	1.69	1.0065	1.25
IV	No yeast, no starter.........	1.0000	0.99	1.0079	1.85	1.0078	1.18

Anisim
Pressed September 15, 1916

Cask No.	Treatment	Dec. 9, 1916		March 8, 1917		May 31, 1917	
		Sp. Gr.	Acidity	Sp. Gr.	Acidity	Sp. Gr.	Acidity
			Per cent		Per cent		Per cent
I	Yeast and starter............	0.9988	0.79	1.0137	4.08	....	....
II	Yeast only..................	0.9989	0.65	1.0135	4.14	....	....
III	Starter only................	1.0113	4.2	1.0189	4.96	....	....
IV	No yeast, no starter.........	1.0119	5.41	1.018	4.63	....	....

Wealthy
Pressed September 19, 1916

Cask No.	Treatment	Dec. 9, 1916		March 8, 1917		May 31, 1917	
		Sp. Gr.	Acidity	Sp. Gr.	Acidity	Sp. Gr.	Acidity
			Per cent		Per cent		Per cent
I	Yeast and starter............	1.0057	3.13	1.0157	5.0	....	....
II	Yeast only..................	1.0054	3.31	1.0184	4.58	....	....
III	Starter only................	0.9965	0.78	1.013	4.81	....	....
IV	No yeast, no starter.........	1.0035	2.28	1.0134	4.64	....	....

Patten (Greening)
Pressed September 20, 1916

Cask No.	Treatment	Dec. 9, 1916		March 8, 1917		May 31, 1917	
		Sp. Gr.	Acidity	Sp. Gr.	Acidity	Sp. Gr.	Acidity
			Per cent		Per cent		Per cent
I	Yeast and starter............	0.9987	0.64	1.0047	0.55	1.0038	0.14
II	Yeast only..................	0.997	0.59	1.0042	0.45	1.0049	0.16
III	Starter only................	0.9986	0.50	1.0048	0.60	1.0037	0.21
IV	No yeast, no starter.........	0.9986	0.48	1.0046	0.41	1.0049	0.21

Hibernal
Pressed September 21, 1916

Cask No.	Treatment	Dec. 9, 1916		March 8, 1917		May 31, 1917	
		Sp. Gr.	Acidity	Sp. Gr.	Acidity	Sp. Gr.	Acidity
			Per cent		Per cent		Per cent
I	Yeast and starter............	1.0037	0.81	1.0144	4.34	....	....
II	Yeast only..................	1.0107	3.38	1.0199	6.42	....	...
III	Starter only................	1.0138	4.43	1.0197	5.82	....	....
IV	No yeast, no starter.........	1.011	3.84	1.0187	6.22	....	....

Some difference in results might also have been obtained through the use of commercial yeasts and starters specially prepared for use in vinegar making, but such materials are not readily obtained in Minnesota. As it is very doubtful, because of the difficulty in obtaining them, whether these products would be used to any extent in home vinegar making in this state, no attempt was made to use them in these fermentation studies.

EFFECT ON STRENGTH OF VARYING THE TIME OF ADDITION OF STARTER

A limited experiment was conducted in 1916-17 to determine if any marked effect on vinegar strength could be secured by varying the time of addition of the starter. Six lots of 7.5 gallons of uniform, fresh Wealthy cider in six sterilized 10-gallon casks were placed together under cellar temperature, ranging from 65 to 75 degrees Fahrenheit, and to each cask compressed yeast was immediately added at the rate of one cake to each 5 gallons of cider. To cask No. 1 one pint of a standard Wealthy vinegar was added one week after pressing. Similar additions were made to the other casks in numerical order at intervals of one week. Results of this experiment are shown in Table VIII.

The analyses of December 9, 1916, made a little less than ten weeks after pressing and two months after the first addition of starter, showed a tendency of the vinegars to range in strength proportionately with the length of time the vinegar starter had been in the cask, but on March 8, 1917, all except cask No. 1 were fairly uniform in acid strength. The superior strength of the vinegar in cask No. 1 might be due to the early addition of the starter, but it seems far more probable that this difference is due merely to the variation in behavior of different lots of the same cider under the cask method of fermentation. Certainly the early addition of the starter did no harm in this case.

Relative to variety behavior it is of interest to point out that two lots of this Wealthy cider were well above the standard strength of 4 per cent acetic acid in less than 10 weeks, and that all but cask No. 3 were well above this standard in 22 weeks from the date of pressing. The record of these casks is also shown in Table V, but it is well to repeat that if a cider such as this from Wealthy will produce vinegar of standard strength within six months from the time of pressing, there is nothing to be gained in holding ciders of the poorer varieties from two to four years in the hope that vinegar of standard strength will form eventually.

The conclusions from the evidence in Table VIII are the same as for Table VII so far at least as Wealthy cider is concerned, namely, that a cider which will usually produce a vinegar of standard strength will do so regardless of modifications in the fermentation procedure if kept at ordinary room temperature under the usual methods for cask fermentation.

TABLE VIII

EFFECT ON VINEGAR STRENGTH OF VARYING THE TIME OF ADDITION OF STARTER

Pressed October 2, 1916

Cask No.	Starter added	December 9, 1916		March 8, 1917	
		Specific gravity	Acidity	Specific gravity	Acidity
			Per cent		Per cent
I	10/9/16	1.0138	6.22	1.0196	6.24
II	10/16/16	1.0004	1.31	1.0140	4.17
III	10/23/16	1.0114	3.76	1.0132	3.69
IV	10/30/16	1.0114	4.19	1.0146	4.33
V	11/6/16	1.0070	2.81	1.0140	4.36
VI	11/13/16	1.0041	1.67	1.0150	4.73

COST OF PRODUCTION

The cost of making cider and vinegar at home by means of a hand press and the common cask method of fermentation, of course will vary greatly, but some estimates will serve to give a general idea of the margin of profit which a cider maker may expect.

Apples for cider making are usually of poor grade and unfit for market, and such fruit has little or no value. In the eastern states cull apples sell in normal seasons for about 30 cents per hundred pounds. Granting that Minnesota apples are of equal value for cider making, the bushel basket measure of 40 pounds will be worth 12 cents. With a hand press of average efficiency, each 40-pound lot should yield from 2 to 3 gallons of cider; so the cost per gallon for the apples will range from 4 to 6 cents. Table I shows that one man should be able to press about ten gallons per hour. Under normal labor conditions the cost for labor will be about thirty cents per hour or three cents per gallon. The cost of handling the apples, either picking up in the orchard as windfalls and hauling, or taking from the sorting table, together with the labor involved in washing and sorting, roughly estimated would be approximately ten cents per basket or from 3 to 5 cents per gallon. Interest at 6 per cent and depreciation at 10 per cent for a press costing from $18 to $25 would add, on the basis of a 200-gallon production, 1.5 to 2 cents per gallon. The barrels and casks used would represent an investment ranging from $15 to $30, and interest and depreciation on these at the same rates as for the press would necessitate a charge of from 1.5 to 3 cents per gallon. The cost of handling after pressing and of marketing probably can be kept down to 2 or 3 cents per gallon on the basis of a production of 200 gallons. Small quantities sold rapidly probably will need no preservative, but for quantities of 200 gallons or more it generally will be best to use a small quantity. The use of benzoate of soda is allowed by law in Minnesota for bulk cider, (but not for bottled cider) in quantities not to exceed one-tenth of one per cent. The general practice is to use the preservative at the rate of 1 ounce to 15 gallons, and at the present market price of $3.40 to $4 per pound this represents a charge of from 1.5 to 2 cents per gallon. Summarizing these estimates we have:

	Cents per gallon
Cost of apples	4.0 to 6
Pressing	3.0 to 3
Picking up, hauling, sorting, and washing	3.0 to 5
Interest and depreciation on press	1.5 to 2
Interest and depreciation on casks	1.5 to 3
Handling and marketing	2.0 to 3
Preservatives	1.5 to 2
Total	16.5 to 24

With sweet cider generally selling for 40 cents per gallon the cider maker can safely count on a profit of from 16 to 23.5 cents per gallon. Doubtless by careful management the costs can be reduced below this estimate and the profit correspondingly increased. On the basis of these estimates a basket of apples (40 pounds) which should yield from 2 to 3 gallons of cider, would return a net profit, varying with the yield and cost of production, of from 32 to 70.5 cents. This would appear to be a fair return from cull or waste apples, altho, of course, not so good a profit as would be expected from the sale of first-grade apples.

In making vinegar no preservative would be used, but the "racking" after the first fermentation would cost somewhere near the same amount. There is some loss in handling and from evaporation which will add somewhat to the cost of the finished vinegar, but this item is so extremely variable that an estimate cannot readily be made. No charge is figured for the use of cellar space, as six 50-gallon barrels will take up very little room and this number of barrels easily will hold 200 gallons of cider for fermentation. If there is no furnace and the cellar is heated by a small stove, the fuel used probably would be firewood produced on the farm and the cost would be small. All other charges would be the same as for sweet cider.

As vinegar probably will cost a cent or two more per gallon than sweet cider, it is evident that the advantage in selling lies with the sweet cider as the returns come more quickly and the net profit will be a little higher. Also, there will not be the necessity of watching the vinegar-making process and guarding against unfavorable conditions in the cellar. However, to make the cider into vinegar gives the possibility of a sale when there is no market for sweet cider. As sweet cider can not be kept long, the marketing time is necessarily limited, thus limiting the quantity which can be produced with safety. In contrast to this, good vinegar will keep for a long time if handled properly, so there is practically no limit to the marketing time. For this reason a much larger quantity can be handled with reasonable assurance that all can be sold. The grower must decide which product best meets his conditions. A ready market usually can be built up for either cider or vinegar and the commercial or home apple grower can thereby secure a profitable method of disposal for a poor grade of fruit which otherwise might be wasted.

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The University of Minnesota

AGRICULTURAL EXPERIMENT STATION

COCKROACH PESTS IN MINNESOTA WITH SPECIAL REFERENCE TO THE GERMAN COCKROACH

BY
VERNON R. HABER
DIVISION OF ENTOMOLOGY AND ECONOMIC ZOOLOGY

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COCKROACH PESTS IN MINNESOTA WITH SPECIAL REFERENCE TO THE GERMAN COCKROACH

By Vernon Raymond Haber

Of the various domestic pests of our temperate climates none are more despised, more widespread, or more wary than cockroaches. Not only do housekeepers suffer from the damage done by these insects, but keepers of restaurants, hotels, soda fountains, confectioneries, bakeries, laundries, and many other establishments find their control a serious problem.

DESCRIPTION

Cockroaches may be recognized by their much flattened bodies, in this respect resembling bedbugs. The head is carried beneath the front end of the body with the mouth directed backward between the bases of the front pair of legs. Two black, kidney-shaped eyes partly occupy the top and sides of the head. To the top of the face region, between the eyes, are attached two bristles or hair-like feelers. The legs are somewhat flat and appear frail and delicate, but they are well suited for rapid running. The upper surface of the back end of the body always bears two blade-like structures which may be directed upward or sidewise. The full-grown cockroach may or may not have wings. This depends on the age, sex, and species, or kind. All immature cockroaches are wingless. Otherwise, except that they are smaller and usually of darker color, they much resemble the adults.

HABITS OF COCKROACHES

In greenhouses or places in which favorable conditions of heat, moisture, food, and seclusion prevail, almost any of the wild cockroaches common to a locality may appear. All cockroaches are exceptionally fond of narrow, dark, damp, warm quarters. Those in residences may be found in crevices back of loose woodwork, around sinks and waterpipes, beneath loose wallpaper, or beneath loose paper accumulating on floors or shelves, or in trash baskets. Domestic cockroaches usually remain near the kitchen and pantries.

Cockroaches are most active at night, but in places where they are abundant they may be seen at almost any time, especially if unmolested. As a rule the young ones are less timid than the adults.

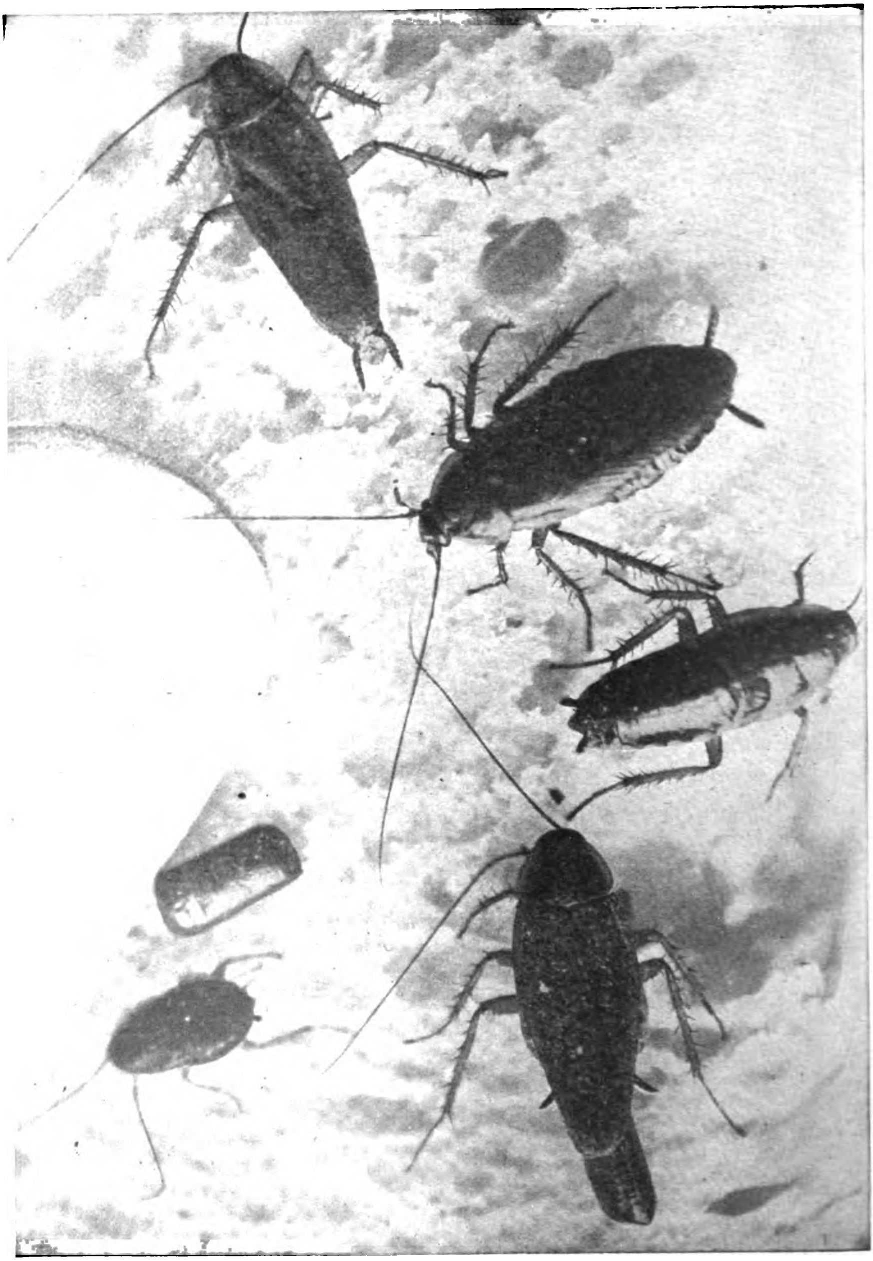

Fig. 1. Cockroaches on Bread, Enlarged   Washburn

Owing to their preference for darkness, the people of ancient times named them "lucifuga," light-shunners.

Cockroaches are biting insects. With their powerful jaws they pinch substances to bits. Left unmolested, they devour almost anything that they can chew. They visit the filthiest as well as the cleanest places and greedily gorge themselves with the filthiest refuse and the choicest of pastries and meats. The legs and feet are provided with small hairs and spines which are well fitted to hold small portions of the materials with which they come in contact. They drop liquid from their mouths on substances over which they run. Other cockroaches come along and drink up this liquid, which may contain bits of any material which the insect has eaten. Cockroaches cleanse their legs, feet, and feelers by passing them through their mouths. They are literally washed with spittle. Thus the portions of food which they do not eat they render unfit for use by running over them. Cockroaches taken from a stable deposited droplets of liquid of the same color and odor as the seepage of the manure. It is easily seen that they can be important factors in spreading certain disease germs. Dangers of this rôle must be considered in the study of the importance of these insects as household pests.

All cockroaches give off a waxy secretion from the greater portion of their bodies. This secretion and the excrement, or dung, give off the so-called cockroach odor. The runways and hiding places are generally characterized by the odor and dung stains. A cockroach taken from one house to another where there are others of the same species, usually has little difficulty in locating the places where its fellows are hidden. In this they seem to be directed by the odor and advantage has been taken of this in trapping them.

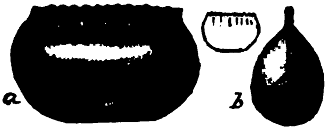

Fig. 2. Egg Case of Cockroach U. S. Bur. Ent.
a. Side view b. End view
Between a and b, outline drawing showing natural size of case.

Cockroaches deposit their eggs in pillow-shaped cases (Figure 2). When an egg case begins to appear at the tip end of the body it is white. As it is filled with eggs it is further pushed out. Fully formed, the case soon becomes about the same color as the first pair of wings or the back of the parent. In this stage it may be left by the mother or she may carry it about until the eggs hatch. Often the mother eats the empty egg case or it may be the first food for the young which hatch from it, or for other cockroaches and insects. A few may be left to decay. In some species the young are developed inside the body of the mother.

The young cockroach, in growing to maturity, must shed its skin several times. This process is known as moulting. Just after each moult the young cockroach is white with black eyes, presenting the appearance of a newly hatched individual. Several hours after moulting it takes on the normal dark color. Cockroaches usually mate several days after becoming adults.

SPECIES OF HOUSEHOLD COCKROACHES OF MINNESOTA

Only four species of domestic cockroaches are found breeding in Minnesota usually. No reports have been received of all four species living in the same building at the same time.

The most common and the smallest of our domestic cockroaches is the German. Of all cockroach infestation in our cities and villages about 90 per cent is the German. The Oriental cockroach ranks next in numbers and in size. The next largest is the Australian. It is rather scarce, but at times appears in greenhouses or similar places which are sufficiently warm and damp and are provided with food. The American cockroach is the largest of our domestic species. None of the domestic species occurs wild in Minnesota. They are found in buildings of cities and villages but seldom in those of rural districts.

Several species of wild cockroaches are found in Minnesota. They may get into residences in the summer, but seldom in such numbers as to be annoying, and usually only temporarily.

GERMAN COCKROACH *Blatella germanica*

Doubtless the German cockroach (Figure 3), is the most troublesome of our domestic cockroaches. In certain localities it is the only species. It is sometimes called the "croton" or "water" bug owing to its having become numerous in New York City at about the time the Croton water system was installed there in 1842. The adults are of a tawny amber-brown color. They possess well-developed wings and the top of the front end of the body is marked by two more or less parallel conspicuous dark brown to black stripes. From the front of the head to the tip of the wing covers, the adult measures about half an inch. Its body is slightly more than an eighth of an inch wide. Females are usually broader, heavier, and darker in color than males.

HABITS

Because of the extreme flatness and the small size of its body the German cockroach can conceal itself in very narrow crevices. This is true especially of the younger ones. They crowd or squeeze themselves into crevices of barely their own thickness. They give off an odor peculiar to the species. In general their habits are much like those of other species.

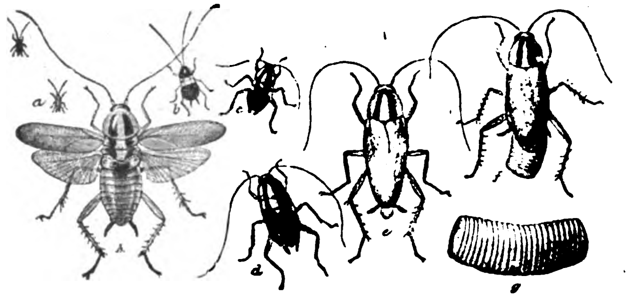

Fig. 3. German Cockroach U. S. Bur. Ent.
a-d. Immature specimens e. Male f. Female with egg case
h. Adult with wings spread g. Egg case, enlarged

LIFE-HISTORY

In from two to four days after mating, the egg case begins to appear at the rear end of the female. If surrounding conditions of heat and moisture are favorable, in about forty-three days the case bursts along the flanged side and the newly hatched young wriggle out. In most cases they emerge while the egg case is still attached to the tip of the body of the mother.

Typically, the German cockroach moults seven times before it is fully grown. If the temperature is maintained at 77 degrees F. (25 degrees C.), in cages well darkened and well supplied with food and water, the complete development is undergone in from 109 to 147 days. In other words, under conditions such as often prevail in nature, the German cockroach may develop from the fertilized egg to the adult stage in from 3½ to 5 months.

The life cycle of this species is the shortest of any of the domestic cockroaches. The sexes mate within a few days after reaching maturity, and breeding may occur throughout the year. This comparatively short life cycle and habit of breeding favor the occurrence of this roach in great numbers where it has become well established.

ORIENTAL COCKROACH *Blatta orientalis*

The Oriental cockroach (Figure 4), is readily distinguished from the German by both color and size. Except at moulting and hatching times these cockroaches are very black. The adults are approximately an inch long and three eighths of an inch wide. Normally the females are longer and broader than the males, the latter appearing frail and weak. In the male, the tips of the wings do not reach the back end of the body; in the female, the upper wings are about three sixteenths of an inch long and are very small in comparison to the body bulk. Often these cockroaches are noticed huddled together, the younger ones crawling over, around, and beneath the older ones.

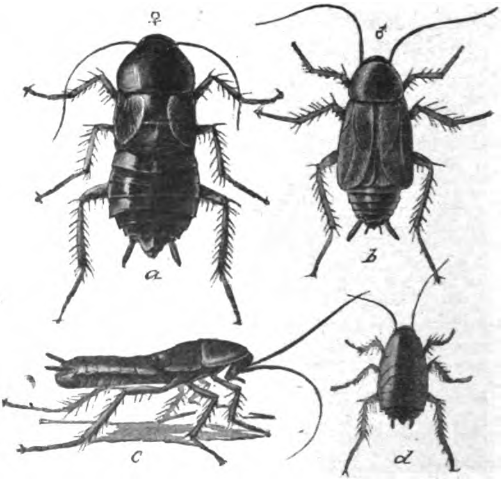

Fig. 4. Oriental Cockroach U. S. Bur. Ent.
a. Adult female b. Adult male c. Side view d. Immature specimen

The female usually produces sixteen eggs in a black pod-like case. After this case is fully formed she may carry it about for several days, but finally deposits it in a favorable crevice. A long time is required for the eggs to hatch. They reproduce most rapidly in warm weather.

In captivity the young grow very slowly. Young of this species have been kept for eighteen months, moulting four or five times during that period and failing to become adults at the end of that time.

This cockroach is among the filthiest of our domestic pests. It has been taken at the mouth of storm sewers, near residences, in veterinary and bacteriological laboratories, in carelessly kept quarters of rabbits and guinea pigs, in underground tunnels, in dairies, and in saloons. Like other cockroaches it eats almost anything but is especially fond of starchy materials.

AMERICAN COCKROACH *Periplaneta americana*

The American cockroach (Figure 5), is a beautiful reddish brown color. The front part of the body is edged with yellow. It is slightly more than an inch and a quarter long and about half an inch wide. In both sexes the wings are very long, extending slightly beyond the back end of the body. The legs are usually lighter colored than the body. Cockroaches of this species may become abundant in dwellings. They are most frequently found in cities, in hotels and packing and slaughter houses.

The egg mass is reddish brown. About seventy days were required for hatching when a temperature of 77 degrees was maintained in dark cages. Usually the egg masses are pasted to floor or ceiling joists or sills in dark places. They may be covered over with bits of paper, finely chewed wood, rags, or even roach dung if no other material is available. As the result of a single mating, one female produced thirteen egg masses, one at a time at intervals of from five to twelve days over a period of about four months. All but the seventh hatched. The egg cases of this species may contain from eighteen to twenty-eight eggs and from twenty to twenty-four are common. These cockroaches, like the Australian and the Oriental, reproduce most rapidly in warm weather.

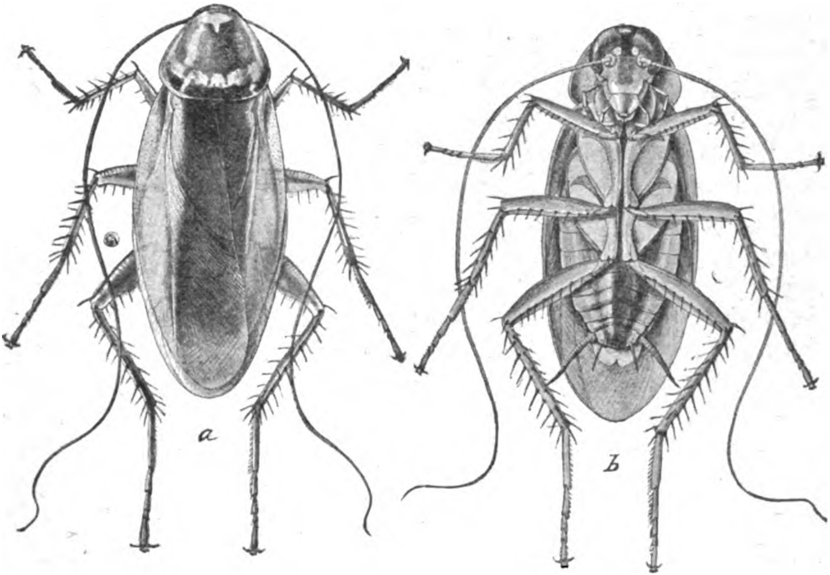

Fig. 5. American Cockroach U. S. Bur. Ent.
Upper and lower views of female.

AUSTRALIAN COCKROACH *Periplaneta australasiae*

The Australian cockroach (Figure 6), is slightly smaller and darker than the American. It is easily distinguished from the latter by the yellow stripe along the outer lateral basal third of each wing cover. The entire length is about an inch and a quarter, the width about half an inch. The wing covers and the wings of both sexes project slightly beyond the back end of the body. As a rule the legs are darker than the body, especially in females. Most specimens come from cities, and particularly from greenhouses and fruit exchanges. They are nowhere abundant in Minnesota.

The egg mass is reddish brown, most commonly pasted to a joist or sill in a dark place. Unlike the egg masses of the American cockroach, those of the Australian are generally left uncovered, otherwise its habits are much the same as those of the American.

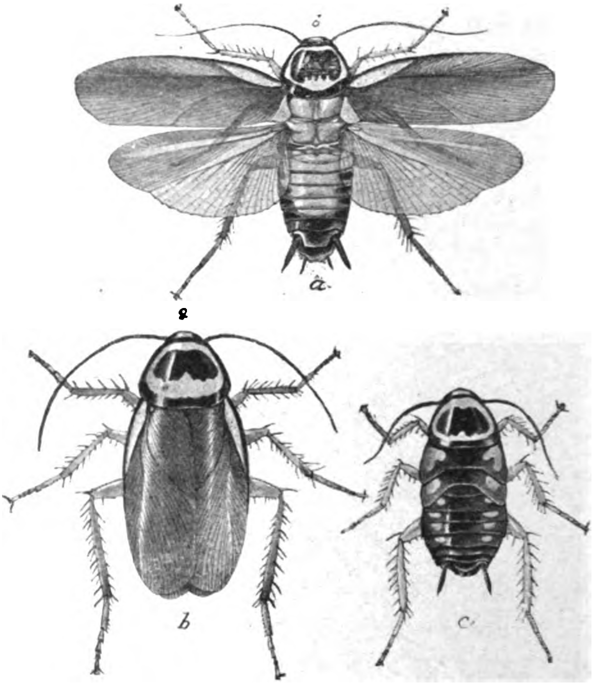

Fig. 6. Australian Cockroach U. S. Bur. Ent.
a. Adult male with wings spread c. Immature specimen b. Adult female

METHODS OF CONTROL

Cockroaches are very active. To reach or to hit them at all effectively with sprays is entirely out of the question as a means of control. The young of all species seclude themselves in such narrow crevices that to reach them requires a fine powder or mist driven with great force.

TRAPPING

Many methods of trapping have been devised and recommended. but the advantages of such methods are often over-emphasized. The satisfaction of seeing great numbers of the pests cornered may produce an unwarranted confidence in the efficiency of the methods employed. However, trapping is of some value as supplemental to other methods and is not to be wholly deprecated. Only those methods that have proved most satisfactory in our experience are described.

For the larger kinds a quart fruit jar, the inside of which should be absolutely clean and smooth, is used. Lean the jar against the wall where the cockroaches congregate, preferably in a corner. Place the jar at such an angle that the cockroaches can easily slide down the inclined inside surface but can not crawl up. The jar should be so placed that it will remain tipped merely enough to keep its position against the wall. It may be baited with clearings from the table such as fruit peelings, especially banana, peach, and apple, or bits or bread or cake. If a few cockroaches of the same kind are placed in the trap, they serve as decoys. The contents of the trap should be kept moist, otherwise the cockroaches are not so readily attracted. Drop the captives into scalding water.

At night put old cloths dampened with dish water in the sink or near their runways and places of seclusion. Darken the room and leave it. At half- or three-quarter hour intervals return with a liberal supply of scalding hot water and dash it upon the cloths, thus destroying many cockroaches which have secluded themselves in the folds of the cloth or beneath it. The dead cockroaches should be collected and burned before the cloths are rearranged to trap more.

Obtain two thin smooth boards about three eighths of an inch thick and of equal length and width. Cleat the ends and one long side edge of one of the boards with one-eighth inch strips if the trap is to be used for German cockroaches or with five- or six-sixteenth inch strips if for cockroaches of larger species. Put both boards into water for several minutes, then smear the cleated surface of the one board and the opposite surface of the other with the pulp from the cut surfaces of apple peelings, bruising or crushing the peelings to give the boards an apple odor. Then fasten the smeared faces toward each other so that a crevice is left between them by the cleats. Hang or lean them into or against the runways. At night plunge the traps into a bucket of scalding water. Clean them, recharge, and replace.

The trap with which we have had the best success in trapping German cockroaches is made of a wide-mouthed bottle (Figure 7) and a piece of ordinary window screen. If available, use a finer meshed screen, say twenty or twenty-five meshes to the inch, to prevent the escape of young roaches that may hatch in the trap. Cut from it a triangle, the base of which is slightly larger than the circumference of the inside of the mouth of the bottle. Roll it to form a cone overlapping the wound edges, and with fine wire closely stitch the two side edges to prevent the escape of cockroaches between them. Five or six of the wires running around the tip end of the cone should be pulled out. Then bend the projecting wires of the apex of the cone so that they form a flare around the outside of the tip. With fine wire weave them so that the cockroaches can not crawl through the meshes thus made. The result is a hollow horn-shaped cone of screen with an outwardly flared collar about its apex, and the hole of the apex not larger than a lead pencil. Next put in the bottle some dampened apple peelings and six or eight living adult cockroaches. Put the cone into the mouth of the bottle, tip end first, with the tip directed upward, and put the mouth thus provided in contact with cockroach runways or places of seclusion. The fermenting apple peelings and the odor of the decoys in the trap attract the cockroaches. Do not wash the inside of the trap more frequently than is absolutely necessary. Chloroform, ether, coal oil, gasoline, carbolic acid, turpentine, or camphor will ruin it for the purpose of catching cockroaches. To empty the trap, jostle the screen cone rapidly up and down in the neck of the bottle (do not force it into the bottle). This will shake the cockroaches off the cone. Immediately empty the contents of the trap into scalding water. Recharge with dampened apple peelings and several adult cockroaches and replace as before. If this trap becomes too dry inside, cockroaches will not enter it, so each evening add a little water. The hole at the

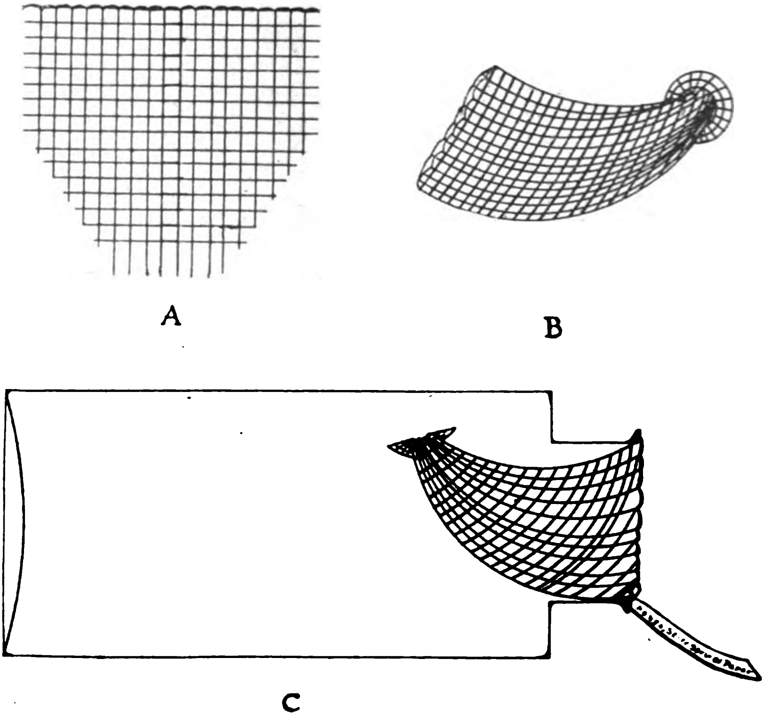

Fig. 7. Efficient Trap for German Cockroach

a. Wire netting cut to form.

b. Cornucopia made by folding netting (a) and fastening it in shape with wire.

c. Wide-mouthed bottle with cornucopia in position and strip of rough paper to form bridge.

tip end of the cone as well as the size of the bottle may be chosen according to the size of the cockroaches one desires to trap.

Generally cockroaches are found where there is a good food supply at their disposal. They are never obliged to visit traps or poisonous baits for food. Thus the use of traps and poisonous baits may prove rather disappointing. To poison or trap cockroaches successfully, all other food material should be put out of their reach. This necessitates keeping the house scrupulously clean. Poisons or traps or both should be set at night, and the victims should be burned or scalded.

DUSTING

Sodium fluoride is an excellent material for use in combating cockroaches. From a dust gun the fine powder is forcibly driven into the runways and places of seclusion, even into cabinet and furniture drawers. With only a fair degree of success, powdered borax may be used in the same manner, but with sodium fluoride results are much better and more rapid. If practical, spray the walls with a fine mist of water and immediately after dash powdered borax against the freshly dampened walls. Thus the powder sticks exactly where thrown if too much is not used. Powdered borax is not poisonous.

Use coal tar products and powdered borax in the water with which the floors of infested houses are scrubbed. In dairies, the milk products may take up the odor and taste of the coal tar products, and these materials should not be used. There live steam under pressure from a hose may be used, care being taken to direct it into the cracks and crevices of walls, ceilings, and floors.

FUMIGATING[1]

Under certain conditions cockroaches can not be economically and successfully controlled by the above methods, and it becomes necessary to fumigate the infested building. For this purpose hydrocyanic acid gas has proved most successful. This gas is extremely poisonous, in fact one of the most deadly poisons to man, and should therefore be handled with the greatest care. In many of the larger cities there are men who are acquainted with the methods of fumigation and make the fumigation of houses to destroy bedbugs and cockroaches, their business. If such a person is available, the safest plan is to hire him to take entire charge of the treatment; if not, the following directions should be carefully followed. Agricultural experiment stations usually have a member of the staff familiar with fumigation, who can assist.

Chemicals necessary.—Hydrocyanic acid gas is generated by the action of sulphuric acid and water upon sodium cyanide. Commercial sulphuric acid will do, and can be purchased much cheaper than the chemically pure. Sodium cyanide 98 to 99 per cent pure should be obtained. Since there are several different kinds of sodium cyanide on the market, care should be taken to get the right kind. A mixture frequently found on the market and sold for fumigation purposes is known as sodium cyanide chloride carbonate mixture. This, besides the sodium cyanide, contains sodium chloride and sodium carbonate. Because of the smaller percentage of sodium cyanide present much larger quantities of the mixture must be used to generate the required quantity of gas. The action of sulphuric acid on this mixture will produce carbon dioxide, and hydrochloric acid. The gaseous hydrochloric acid, altho having little or no insecticidal value, will tend to tarnish metal and hence is not desirable. The sodium cyanide chloride carbonate mixture should therefore never be purchased for fumigation purposes.

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[1] This section has been revised by Prof. William Moore, who is responsible for details of recommendations.

A powder consisting of pure sodium cyanide is also found on the market. This is manufactured for soil fumigation and should not be used for house fumigation since, being a powder, the poisonous gas is generated too rapidly and is accordingly too dangerous.

The sodium cyanide, 98 to 99 per cent pure, should be purchased in lump form. Sodium cyanide in the form of eggs, each weighing one ounce, is put on the market by one manufacturer under the name of Cyanegg. This is a very convenient form since weighing and breaking up of the lumps with its attendant dangers is unnecessary.

Preparation for fumigation.—Buildings containing more than one family should not be fumigated unless everyone can be removed from the building during the fumigation. Persons living in adjoining or neighboring houses should be warned and it would be well to obtain their approval of the fumigation.

Before fumigation the house should be gone over carefully and all cracks, crevices, and openings tightly sealed to prevent the escape of the gas. Newspaper or glazed paper is the best material to use. Paste the paper over the crevices, or, if too large for this, a tight wad of newspaper may be used. Openings such as pipe holes, fireplaces, and registers, should be made as nearly gas tight as possible. Particular attention should be given to the windows. Food materials, particularly those containing moisture, should be removed from the house. Dry food, such as flour, may be left, providing it is thoroly aired before being used. House plants, cats, dogs, canaries, goldfish, or any living thing must be removed. Nickel sometimes is slightly tarnished by the gas but this can be prevented by covering it with a dry towel or cloth.

Since it will be necessary to ventilate the house after the fumigation before it can be entered, several windows on each floor should be so arranged that they can be opened from the outside. A cord may be attached to the windows on the second floor by means of which the window can be lowered. The windows selected should be carefully examined and tested before the charge is placed in the house.

Each room should be carefully measured and its capacity in cubic feet determined by multiplying the length by the width by the height. The dose for each room can then be calculated, using one ounce of sodium cyanide to each one hundred cubic feet capacity. The hydrocyanic acid gas is generated in stoneware or earthenware jars or crocks, never in metal containers. Four-gallon crocks are a convenient size, but a charge for such a crock should not exceed three pounds of sodium cyanide. With larger doses the liquid is likely to boil or bubble over on the floor. If more than three pounds is needed for one room, two jars should be used.

The rugs or carpets should be rolled back and several thicknesses of newspaper spread in the center of the room on which the jar should be placed. The object of this precaution is to protect the floor from splashes of acid occurring during the generation of the gas. A container of ashes may be placed under the jars as a further protection.

Preparing the charge.—Everything being ready, the sodium cyanide is made up into little bundles containing the correct charge for each room. If lump cyanide is used it must be broken up and weighed. This process should be carried on outdoors in a safe place. If cyanegg is used the eggs can be directly counted out since each weighs one ounce. If a fraction of an ounce is required, it is most convenient to call it an ounce. The charge for each room is then tied up in a piece of cheesecloth or muslin and carried to the proper room. It may be placed in paper bags but in the writer's experience the paper sometimes chars about the cyanide, protecting it from the action of the acid and thus reducing the dose.

The water and acid are next measured out. This also had better be done outdoors. For each ounce of sodium cyanide to be used in a room, four fluid ounces of water are measured out and placed in the proper jar. The sulphuric acid is next added, using one and a half fluid ounces of acid to each ounce of the cyanide or each four fluid ounces of water. Care should be taken that none of the acid is splashed on the hands, face, or clothing, as it causes severe burns. For this reason the acid is poured slowly and carefully into the water. Should any splash on the clothing a drop of ammonia will neutralize it. A splash on the hands or face should be washed off with water, and soap smeared over the spot to neutralize it. Ammonia should not be used on the hands or face. The mixture of the acid and water generates considerable heat and the jars should be put in position while still hot.

Starting the fumigation.—Everything is now ready to set off the charge. Have one last look around to see that everything that should be removed has been removed. Accidents have occurred by persons returning to the house to remove something after the charge is started. Two persons can most conveniently send off the charges. Their routes should be so arranged that they meet at the stairway. It is advisable for the operators to go through the rooms and plan their route before attempting to put in the charges. This prevents confusion when actually placing the cyanide in the jars. Care should be taken not to set off a charge in such a position as to cut off the worker from the stairs. Start putting in the charges on the top floor. Do not become excited but move quickly from room to room dropping the package of cyanide into the jar and leaving the room at once. Having finished the top floor, repeat the procedure on the floor next below until all the charges have been set off. The workers should finish at a basement or a first floor door and leave the house at once. No time should be wasted from start to finish since one good breath of the concentrated gas is sufficient to cause death. On leaving the house, lock the door and put a notice on the doors warning people away. If you now find that you have forgotten the cat leave her for she is no doubt already dead, and it would only mean your own death to return for her. The temperature of the house during fumigation should be about 70 degrees F. The fumigation should continue for twelve or even twenty-four hours. This dose will kill cockroaches, bedbugs, fleas, carpet beetles, moths, rats, and mice. If the house has been made quite tight, the eggs of cockroaches and bedbugs will also be killed. thus entirely freeing the premises of these pests.

Small pieces of cyanide lying about where it was measured should be buried. The utensils used should be thoroly washed. Any cyanide left over should be put in a tight container and carefully labeled. Exposed to the air, the cyanide decomposes.

Ventilating the house.—When it is time to remove the charge, carefully open the windows that have been previously arranged to open from the outside. Open the doors if possible and allow the house to air for about half an hour. On entering an almond-like odor will be noticed and if this is at all strong a longer airing will be necessary before venturing into the house. The jars should be removed and the contents poured into a hole in the ash pile or in the garden and covered over. The jars should then be carefully washed. Any water standing about in the house will have absorbed the gas and should be at once poured out. Dry food which has been in the house should be carefully aired before being used.

Hydrocyanic acid gas fumigation is dangerous and should be carried out only by an intelligent person who will carefully follow directions and take no chances.

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The University of Minnesota

AGRICULTURAL EXPERIMENT STATION

SORGHUM AND SORGHUM SIRUP MANUFACTURE

BY
J. J. WILLAMAN AND R. M. WEST
DIVISION OF AGRICULTURAL BIOCHEMISTRY
AND
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SORGHUM AND SORGHUM-SIRUP MANUFACTURE

By J. J. Willaman, R. M. West, and C. P. Bull

I. INTRODUCTION

The growing of sorghum cane for the production of sugar foods has passed through many trials. The use of sorghum for sirup increased rapidly up to 1880 in all the sorghum growing regions of the country. About 1880 the Bureau of Chemistry of the United States Department of Agriculture undertook to investigate sorghum as a source of granulated sugar. The prospects looked very promising at first and many thousands of pounds of sugar were actually manufactured. However, the results were uncertain. Whether or not a good yield of crystallized sugar could be obtained from the juice depended too much on the stage of maturity of the crop, weather conditions, and the variety used. Sorghum was therefore abandoned as a source of granulated sugar. For sirup, however, it continued to be used rather extensively, but in constantly decreasing amounts. In Minnesota the amount of sirup produced decreased from 543,000 gallons in 1879 to 145,000 gallons in 1909, and to about 140,000 gallons in 1918 (see Table I). The reasons for this are simple: (1) The sugar beet has made granulated sugar increasingly cheap and abundant. (2) Most of the sirup has been made in a small way, by crude methods which gave inferior and uncertain products, and the sirup has been consumed locally. Under these circumstances sirup making is a disagreeable, time-consuming job, and the farmers have preferred to expend their labor in more profitable occupations. In other words, sorghum sirup making is one of those industries, which, like the spinning of wool and the churning of butter, at one time carried on by the farm family for its own benefit, have now been delegated mostly to larger, centralized organizations. A coöperative sorghum sirup factory organized on a basis similar to that of a coöperative creamery, could, however, be made a profitable enterprise in many communities.

The demand for sorghum sirup has been maintained. This is shown in Table I by the greatly increased value of the product in the face of the decrease in the amount produced.

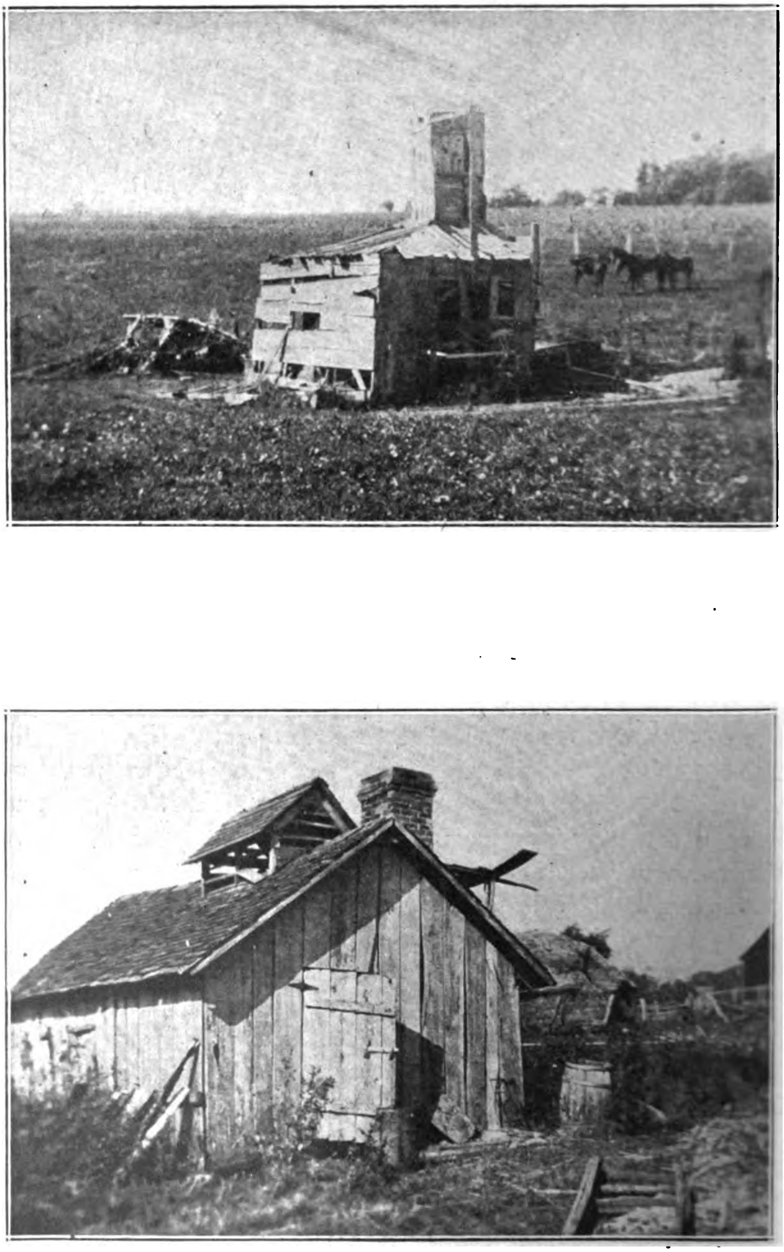

Fig. 1. Sorghum Sirup Outfits of the Early Days
It is easy to be seen why sirup of uncertain quality was produced, and why the makers were glad to abandon their "sorghum boilers" when other forms of sugar became cheap.

TABLE I

PRODUCTION AND VALUE OF SORGHUM SIRUP IN MINNESOTA SINCE 1879

Date	Amount of sirup	Value per gallon	Total value
	Gallons		
1879	543,000	$0.30	$162,900
1889	340,000	0.35	119,000
1899	157,000	0.37	57,900
1909	146,000	0.55	80,700
1918*	140,000	0.90	126,000

*Estimated

Personal observation and correspondence with a large number of wholesale grocers and jobbers in the state have shown that in many quarters the demand for sorghum sirup of high quality far exceeds the supply; that the present market supply could readily be disposed of many times over at good prices, and that an enormously greater amount could be used for blending with corn sirup to make a milder and cheaper product. By the use of advertising, and by manufacturing and selling at a lower cost, the present yearly output of 140,000 gallons could easily be increased to 1,000,000 gallons. In fact, there has been evidence during the last few years of a keen revival of interest in sorghum sirup making in the North Central states. Dealers in sirup machinery state that there was an increase of from 10 to 25 per cent in orders during 1917 and 1918, and that this revival was not occasioned by the temporary sugar shortage, since the erection of a sorghum sirup factory of good size is not a temporary proposition.

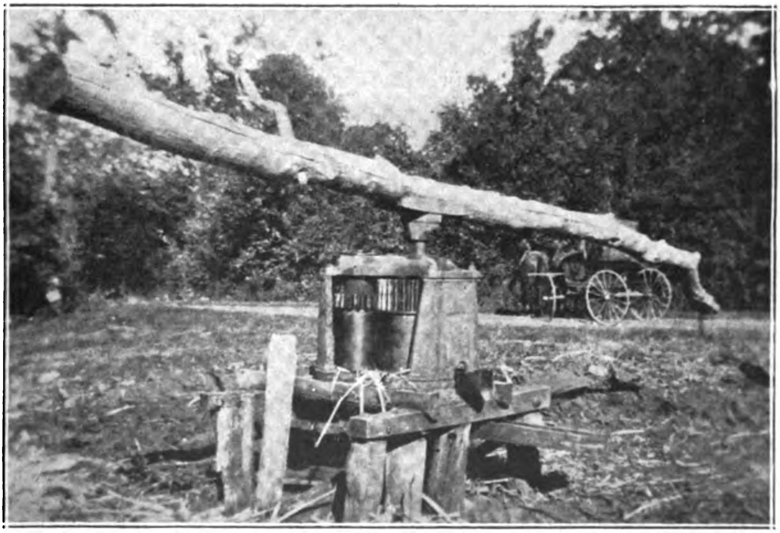

Fig. 2. Small Cane Mill Operated by a Horse Sweep

Such mills are very wasteful of juice as they never extract more than 900 pounds per ton of cane, whereas heavy steam-power mills extract as much as 1,200 or 1,300 pounds.

PRESENT STATUS OF SORGHUM SIRUP INDUSTRY

At the present time about three fourths of the sirup in Minnesota is made on a factory scale, and the rest on the small local scale already mentioned. We must recognize at the outset these two distinct types of operation in the sorghum sirup industry. The one employs heavy mills, steam evaporation, clarification processes, machine harvesting of the sorghum, and other large-scale operations which make for low cost of manufacture and high quality of product. Such factories make from 10,000 to 40,000 gallons of sirup a season. The other type of sorghum factory employs a small mill, usually operated by a horse sweep; a direct fire evaporator; much hand labor in harvesting; and no clarification. Factory methods of the latter kind make for high cost of production and for poor and uneven quality of product. Factories using these methods make less than 2,000 gallons a season, most of it being custom work for neighboring farmers. As will be brought out in the cost data given later, small-scale production is very uneconomical, the cost being from 60 to 80 cents per gallon of sirup. On the large scale it is about half this. If the sirup wholesales at from 80 to 95 cents,[1] the industry can be made a profitable one when correct manufacturing processes are followed, thus insuring low cost and uniformly high quality of product.

The present bulletin is especially designed to meet the requirements of the large-scale manufacturer. It gives all necessary directions for growing and harvesting the cane and for manufacturing the sirup, and discusses the composition and uses of the sirup, production costs, and market possibilities. We are not disposed to advocate that the small and intermediate factories quit operating, for local conditions may be such as to enable these plants to be operated at a profit, but we feel that, as a rule, the small-scale manufacture of sorghum sirup is not an economic procedure, that the chance of failure is relatively large, and that factories at present operating on such a basis can profitably install additional equipment, thus increasing their output of finished sirup and also the margin between the cost of production and the selling price of the sirup.

---

[1] These are 1918 prices.

II. THE SORGHUM PLANT

BOTANY OF SORGHUM

The word sorghum is a more or less generic name for a group of plants belonging to the grass family (*Gramineac*). These are conceded to have been derived from the wild species,[2] *Andropogon halepensis* (L.) Brot., found abundantly in the southern climates of the old world. This species was introduced into the United States and is known as Johnson grass. The common forked or finger grass (*Andropogon furcatus*) growing on waste places in Minnesota is a related species, but does not have the underground root stalks common to Johnson grass.

Sorghum (*Andropogon sorghum*) has been recorded as a human food since the dawn of history. It includes all groups of sorghum under cultivation, such as sweet or saccharine sorghums, grain or non-saccharine sorghums, and broom-corns. These are classed in several ways according to their physical structures and chemical content. Thus they are classed as sweet sorghums and grain sorghums; saccharine and non-saccharine; those with juicy pith and those with dry pith. The writers prefer the saccharine and non-saccharine grouping, as that clearly defines them as sirup or forage varieties. Minnesota is not much concerned with any except the saccharine group, botanically known as the Sorgo group. Kaffir and Milo have slightly sweet juices, but can not be used for sirup production. Broom-corn, Kowliang, Shallu, and Durra (also spelled Dhura) do not have a sugary juice and therefore naturally fall into the non-saccharine classes. The seeds of the various groups are not very different in form tho they vary somewhat in size. Hence farmers are often confused in the identity of the sorghums and deceived in attempting to grow them.

In habit of growth, sorghum plants are similar to corn. The stem and leaves are pale green and are more slender than corn. The stalks are woody on the outside and pithy inside. On the outside of the stalk is found a "bloom," a powdery substance similar in appearance to mildew. The plant grows from five to twelve feet tall, according to conditions and variety. The seed head, a loose or a compact panicle, is borne on top of the stalk. The seeds are borne in glumes similar to those of millet. The roots are fibrous and very numerous. The feeding zone of the roots is largely in the upper six inches of the soil, but the roots extend from two to four feet on all sides of the plant and from four to six feet deep. When young the plants are rather tender and grow very slowly, but after two or three weeks they become very vigorous. See figures 3, 4, and 5.

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[2] An exhaustive history of sorghum is found in Bull. 175, Bur. Pl. Ind., U. S. Dept. of Agr.

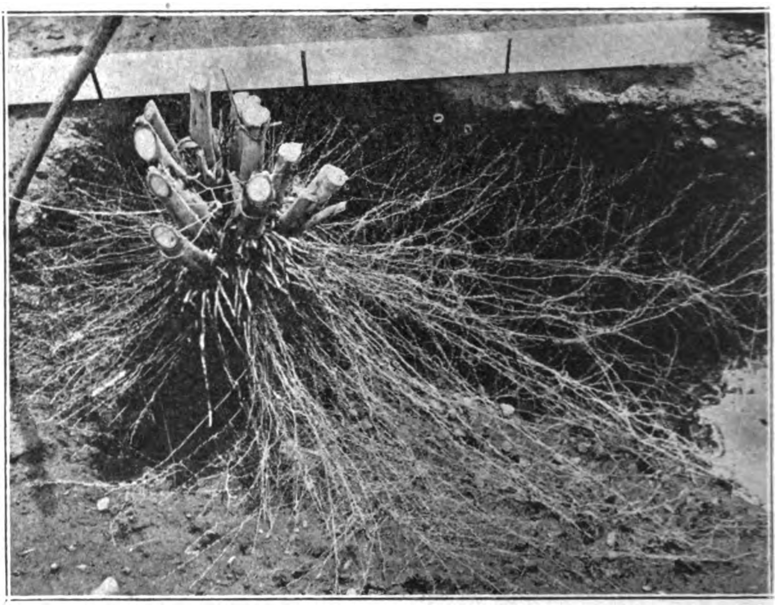

Fig. 3. Roots of One Mature Sorghum Plant Grown Apart From Others
Under such circumstances a plant is prone to stool (sucker). The dirt was washed free from these roots thus leaving them in their natural position. The very fine branches were all destroyed by the stream of water when washing the earth away from the main roots.

VARIETIES OF SACCHARINE SORGHUMS

Many varieties of saccharine sorghums are now on the market. All are supposed to have been developed since the original importation from China in 1853. Only a few varieties have been used over a large area. The varietal characters are marked chiefly by the different forms of the seed head. The saccharine or sweet sorghums are divided into four groups, Amber, Orange, Sumac (or Red Top), and Gooseneck.

Amber matures earlier than the others and for that reason is the sorghum usually raised in the northern states. It came originally from China, and was brought to Minnesota from Indiana. It is characterized chiefly by a rather spreading seed head, slender stalk, narrow and comparatively few leaves, and black, obtuse, outer flower glumes. See figures 6 and 7. Several varieties of Amber are on the market.

Orange is next in earliness. This was introduced from Africa. It is not extensively grown in Minnesota. It is safe to say that no seed is produced in the state. On a comparative basis, Orange has larger stalks, more and larger leaves, more compact and larger seed heads than Amber.

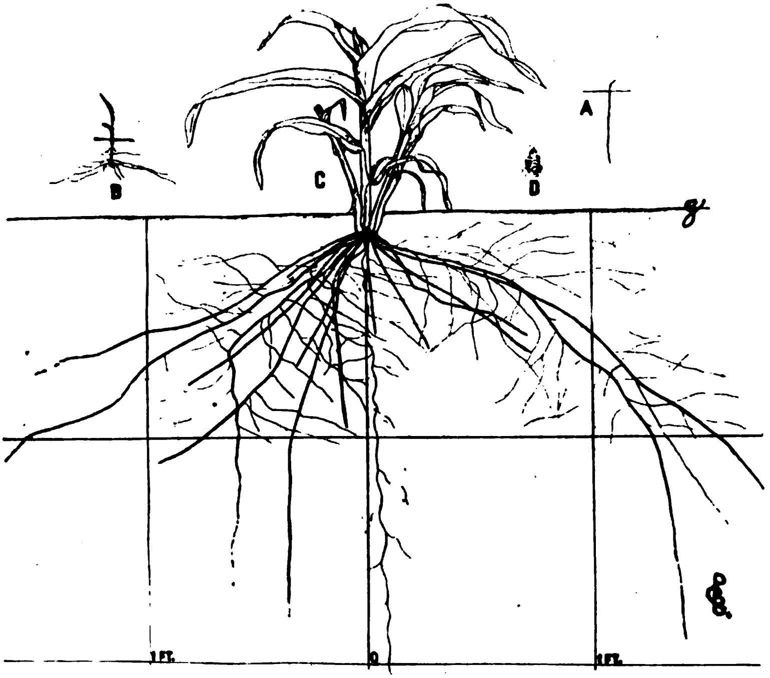

Fig. 4. Sorghum Plants

The development of root systems is shown at A, at the age of 10 days; at B, 24 days; and at C, 45 days; and the growing point of the central stalk, D, which at 45 days is barely above the surface of the ground (g). Note the developing of the root system (A and B) between the seed and the surface of the soil. It is at this point that later develops the main root system of the plant as shown at C. The primary "seedling" root system gradually ceases to develop and function as the main system develops. The plant growth is rapid after the main system becomes well developed, which is at about 40 days.

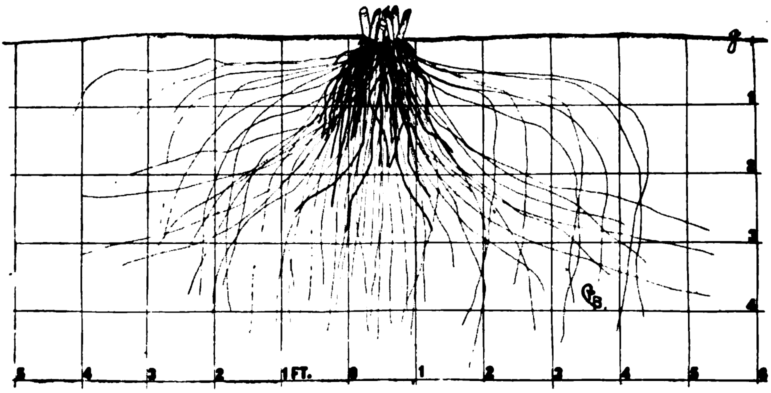

Fig. 5. A Sorghum Plant Root System at 95 Days from Date of Sowing the Seed

The roots here shown are only a few of the largest and longest. No branches are shown. The roots are illustrated as nearly as possible in the same positions as observed when washed free from soil. Note the length of the roots and the distance from the plant in the upper one foot of the soil. The branches of the roots shown came much nearer the surface of the soil.

Sumac (or Red Top) comes from Natal. The seed head is thick and compact. The leaves are broad and the plant gives an impression of stockiness. The seeds are reddish brown and smaller than those of other varieties. It matures fairly early but is mostly grown in the South.

Gooseneck is thought to have descended from an African variety. Its name was suggested by the recurved upper part of the stalk which inverts the seed head. The seeds are pale red in color. The stalks are tall and rather coarse. This variety is probably the latest maturing of all.

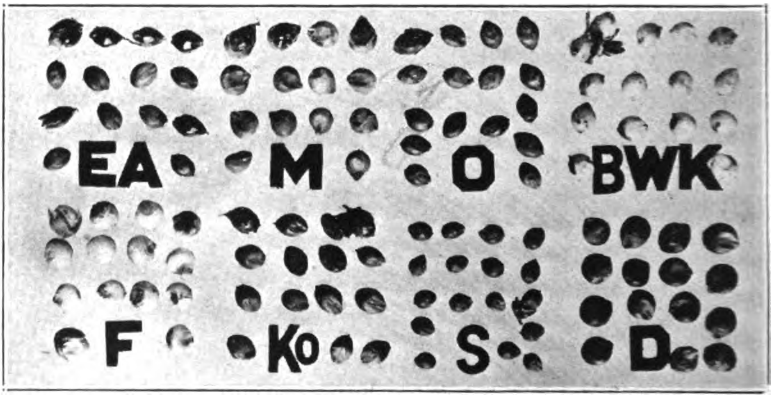

Fig. 6. Seeds of Some of the Varieties of Sorghum

EA, Early Amber; M, Milo; O, Orange; BWK, Blackhull White Kaffir; F, Feterita; Ko, Kowliang; S, Sumac; D, Durra. With the exception of the Durra, each variety has one or more seeds shown in the hull. In color the varieties are as follows: EA, dark reddish brown; S, brownish red; M, pale red; F, milk white; BWK, white with dark spots; D, Light red; Ko, muddy red; O, very dull brown with just a hint of red. A "pebbled" or wrinkled surface of the seeds of the non-saccharine groups is not uncommon.

Amber is the variety best adapted to northern climates and is the only one recommended for Minnesota. Its early maturity makes it the favorite. A selection from Amber made by the veteran sorghum grower and manufacturer, Seth H. Kenney, Waseca County, has become known as Minnesota Early Amber and is widely used in the North Central states. There are many strains now grown, but the name Amber is and should be retained. It will help to distinguish them from the other varieties not so well adapted to Minnesota.

The following key shows the relation of the groups of saccharine sorghums:

CLASSIFICATION OF THE SACCHARINE SORGHUMS[3]

Order.......*Gramineae*
Tribe........*Andropogoneae*
Genus.......*Andropogon*
Species......*A. Sorghum* var *vulgare*
Class........*Sorgo*

---

[3] Montgomery, E. G. "The corn crops," pp. 296-7. The Macmillan Co., New York, 1916

A. Peduncle and panicle erect
1. Panicle loose, open, branches spreading to horizontal or dropping;
(a) Rachis two thirds as long to equaling the panicle
Empty glumes black, hairy I. Amber
Empty glumes black, smooth II. Minn. Amber
Empty glumes red III. Red Amber
Empty glumes light brown IV. Honey
(b) Rachis less than half the length of the panicle.
Panicle light, branches drooping, seeds orange to red V. Collier
Panicle heavy, seeds orange VI. Planter's Friend
2. Panicle close, compact
Empty glumes equal to seeds, seeds red VII. Orange
Empty glumes half as long as the small seeds, seeds dark red VIII. Sumac
Empty glumes narrow IX. Sapling
B. Peduncle recurved (goosenecked) or sometimes erect
Panicle black, glumes awned X. Gooseneck

VARIETY TESTS AT UNIVERSITY FARM

Thirty-five different seed stocks of saccharine sorghums have been received and grown at University Farm since 1895. Sixteen of these are of the Amber group. Among the thirty-five are Minnesota Accession Nos. 5, 6, 7, 8, 9, 12, 13, 14, 15, 25, 30, 38, and 39, received from the United States Department of Agriculture. The rest have been obtained from seed houses and from individuals growing sorghum, mostly in Minnesota. Nos. 5, 6, and 8 are of the same origin as 13, 12, and 14 respectively, and were from selected seed from Medicine Lodge, Kansas. These had all been selected for high percentage of sucrose. Nos. 10 and 15 are from the seed stock of Seth H. Kenney, Minnesota.

In 1900 and 1901 a test was made of Accession Nos. 5 to 10 inclusive, and 15. They were planted in drill-hills, 39 by 12 inches apart, 6 seeds per hill. Table II gives the yield of cane and the weight of juice from 500 pounds of cane from each plot.

TABLE II
VARIETY TESTS AT UNIVERSITY FARM, AVERAGE FOR 1900 AND 1901

Variety	Dept. No.	Minn. No.	Weight of green cane per acre		Sugar content	Weight of juice	
						From 500 lbs. of cane	Per acre
			Pounds	Tons	Per cent	Lbs.	Lbs.
Colman	4308	5	19,510	9.75	12.28	181.0	7,059
Collier	4309	6	22,440	11.22	13.47	218.0	9,726
Folgers	4310	7	25,340	12.67	12.65	158.1	7,999
Amber	4311	8	23,355	11.66	12.66	168.8	6,050
Edgar	4312	9	21,350	10.68	12.85	199.3	8,503
Minn. Early Amber	....	10	16,880	8.44	14.46	184.5	6,217
Minn. Early Amber	....	15	15,120	7.56	12.85	130.0	3,930
Home Grown Amber	....	..	20,440	10.20	14.04	111.5	4,704

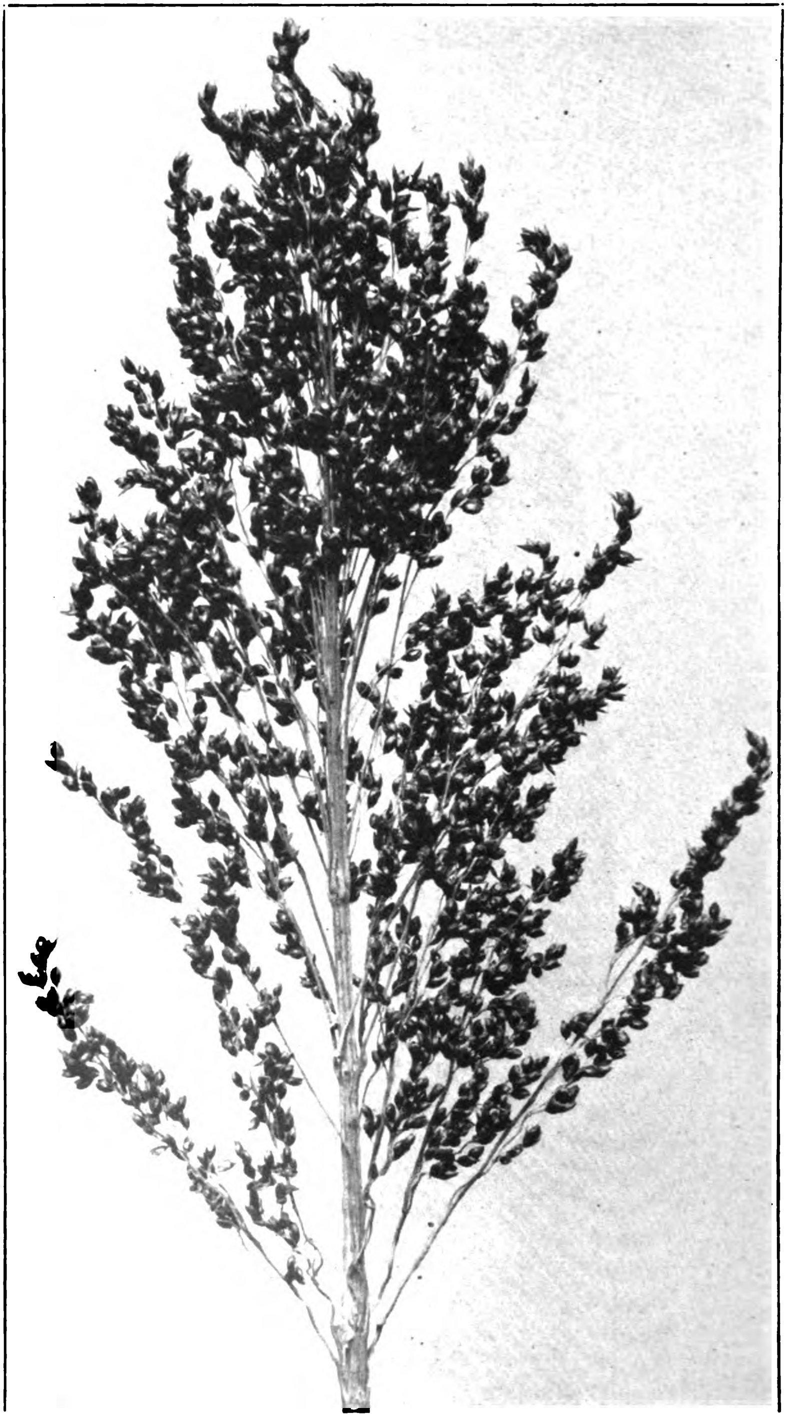

Fig. 7. A Typical Seed Head of Early Amber Sorghum

As the plants in the field appear at harvest time, a few seed heads will appear more spreading and open; a great many will be more compact. The branches and spikelets droop more and more as the seeds near the "dead ripe" stage. Seed heads will average from an ounce and a half to two ounces in weight.

It will be noticed that Minnesota Amber strains yield much less than the others. This is without doubt due to the earlier maturity and consequent shorter growth. Indications are that the percentage of sugar in the Minnesota Ambers is high. The amount of juice from 500 pounds of cane varies greatly among the varieties. This would indicate the greater succulency of the less mature varieties from the southern seed. Unfortunately the amount of sirup in the juice or per acre was not obtained.

Sorghum was given no attention at University Farm from 1901 to 1912. In 1912 and 1913 varieties of sorghum were again tested. Twelve stocks of seed were obtained from various sources and planted in rows 42 inches apart. The plants were thinned to about 10 inches apart in the row. Aside from general observation of the plots, notes were taken on the average height, evenness of height, maturity, relative diameter of canes, character of seed heads, and yield of cane per acre.

Table III shows great variation in all the characters observed. The yield of 7.6 tons per acre of the imported Chinese was lowest and that of Orange, S. P. I.[4] 17556, highest among those with the two years' average. The Ambers do not show any outstanding differences. Amber, Accession No. 20, is next highest in yield; and White Amber, Accession No. 25, is next lowest. In percentage of maturity, the northern grown seed, Accession Nos. 27, 31, 32, and 34, seem to have a slight advantage. The commercial seed stocks, Accession Nos. 18, 19, and 20, show decided lateness, indicating that much of the sorghum seed obtained in Minnesota is grown in the South. Additional tests are necessary to further emphasize the comparative value of the varieties, and definite improvement is necessary to secure seed stock of stable qualities.

The season of 1912 was noticeably favorable to forage production, but decidedly unfavorable to the maturity of the crop. Maturity notes taken September 28 ranged from 10 to 65 per cent. Estimates were made on the basis of seed development, the stage when considered best for sirup making being regarded 100 per cent. South Dakota Amber was the highest, Orange S. P. I. 17556 the lowest. The weight of green canes ranged from 8.1 tons for the Chinese to 23.5 tons for Early Amber, Accession No. 20. Average maturity was 45 per cent and average weight 18.4 tons.

Contrasted with 1912, the season of 1913 seemed to be very favorable to maturity but not so favorable to yield. Notes taken September 16 showed an average maturity of 82 per cent and an average yield of 10 tons per acre, not including Accession Nos. 31, 32, and 34, which were not in the 1912 test. South Dakota Amber was again highest in maturity, having 95 per cent. Early Rose, a strain selected by Mr. Kenney, was also 95 per cent in maturity and medium in yield in the 1913 test. In height, the varieties held their relative positions regardless of the differences in maturity and yield.

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[4] Abbreviation for "Seed plant importation," U. S. Dept. of Agr.

TABLE III

SORGHUM VARIETY NOTES—AVERAGE OF 1912 AND 1913

Variety	Accession No.	Height	Evenness in height[*]	Seed maturity [†]	Yield of green cane per acre[‡]	Character of seed heads
		Inches	Per cent	Per cent	Tons	
Amber	18	86	72	67	14.6	Short, open, and spreading
Orange	19	92	82	52	15.2	Short, compact
Amber	20	96	82	56	17.9	Short, compact
Southern Cane	22	96	70	80	15.1	Rather short, open and spreading
S. P. I. 29166	25	81	82	62	10.7	Open and spreading
White Amber Imported Chinese	23	92	85	70	7.6	Large, open, and spreading
South Dakota Amber	27	100	72	80	12.4	Open and spreading
S. P. I. 17548 Red Amber	28	97	82	70	15.3	Rather long, medium spreading
S. P. I. 17556 Orange	30	96	87	47	19.1	Large, very compact
Early Orange	31	90[‡]	80	85	9.8	Compact
Early Rose	32	88[‡]	85	95	8.7	Open
Pius Amber	34	90[‡]	85	85	3.7	Open

[*] Evenness in height was slightly lower in 1912 than in 1913. Uneven height is regarded as an indication of lack of selection which would lead to uniformity of the plants.

[†] Stage of maturity very much lower in 1912 than in 1913.

[‡] 1913 results only.

CULTURE OF SORGHUM

THE SOIL

Soil type is a factor in growing sorghum for sirup, only from the standpoint of yield. The best yields are produced on good loam and clay loam soils. Profitable yields are secured on lighter or sandy soils when the necessary supply of plant food is maintained. Sorghum is successfully grown in Minnesota on the sandy lands between Duluth and the Twin Cities; on the hardwood timber lands characteristic of Hennepin, Wright, Carver, LeSueur, and adjacent counties; on the prairie lands of south central sections, and on the heavy soils of the southeastern and southwestern parts of the state. Figure 8 shows the regions in Minnesota where successful sorghum cultivation is possible. Only the southern half of this range is adapted to commercial sirup production, however, since this demands a mature crop and a fairly long working season.

Sorghum produces best on soils recognized as warm, well drained, and quick. Production depends more on the fertility of the soil than on its physical make up. The plant responds readily to the application of manure. On the lighter soils the manure should be plowed under in the fall or well worked into the surface as a top dressing. For top dressing, manure with weed seeds should be avoided. In either case manure with much litter should not be used.

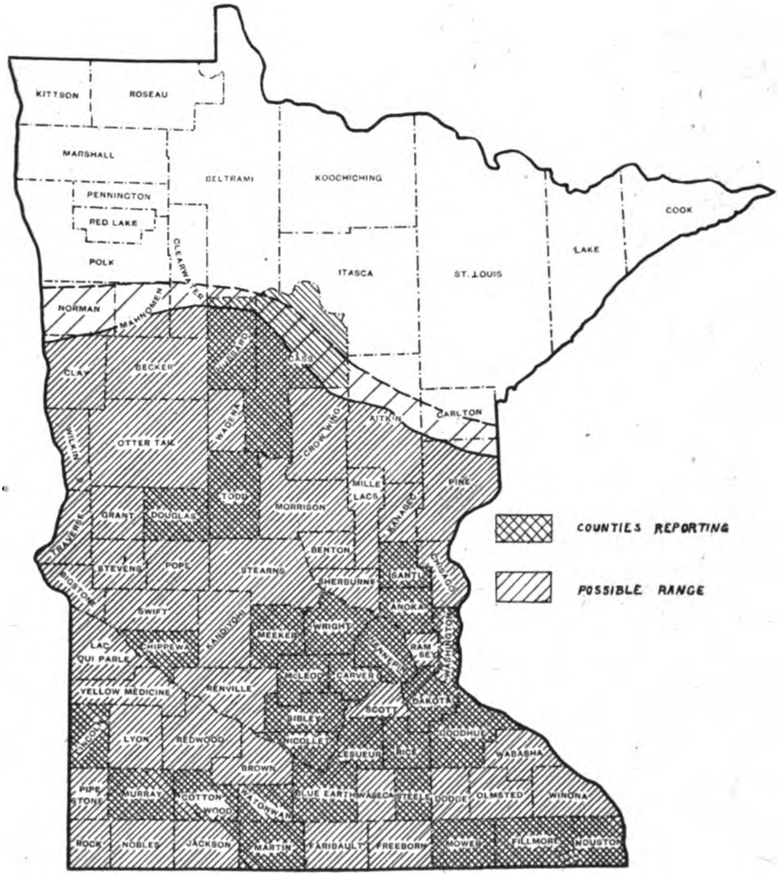

Fig. 8. Range of Successful Sorghum Growing in Minnesota

Sorghum fits well into crop rotation schemes. It may take the place of corn in any rotation suited to the particular needs of the farmer. Table V suggests desirable rotations for three, four, and five years.

In the five-year course the sorghum may occupy the part of the field in which corn is to be grown, or the entire field. Manure is applied to the meadow, which is fall-plowed. Where sorghum is grown on a small scale it can take its place in the minor rotation. In the three-year course the grain may be rye or any cereal. The meadow may be clover or any annual pasture crop. In the four-year rotation, corn should either precede or follow the sorghum; follow the meadow and precede the grain; or the corn should be left out and another year of meadow or pasture take its place. There may be some difficulty in preparing the seedbed for sorghum following corn, but if the disk is used before the field is plowed, the difficulty will be reduced to a minimum. As a fertilizing crop, beans, field peas, soybeans, and clover the year before the sorghum is planted will prove satisfactory.

TABLE IV
SUGGESTED ROTATIONS FOR SORGHUM

Major 5-year course	Minor 3-year course	Minor 4-year course
Corn and sorghum	Sorghum	Corn
Grain	Grain	Sorghum (manure)
Grain (seeded)	Meadow (clover)	Grain (seeded)
Meadow		Meadow
Meadow (manured)		

THE SEEDBED

The preparation of the upper three inches of the soil in order to provide a good seedbed is a factor that must receive careful attention in the growing of sorghum. Three conditions are necessary for success in giving the plants a good start: (1) A fine, firm seedbed, (2) adequate moisture, (3) freedom from weeds. Plowing in the fall and working early in the spring with a disk or harrow will practically insure all three conditions. Spring plowing is likely to be delayed, thus inviting the early development of weeds and a loose soil. In dry seasons, spring plowing may cause failure. Spring-plowed land must be thoroly compacted by disking, rolling with a subsurface packer, and harrowing. Each day's plowing should be harrowed at the close of the day to maintain a fine soil texture. Under some circumstances it may be necessary to harrow twice a day, that is, the forenoon's plowing is harrowed at noon and the afternoon's plowing before leaving the field at night.

A lumpy seedbed is likely to be dry and to have large air spaces. If the land is fall-plowed the weeds should be kept down before planting time by thoro disking and harrowing. This will not only reduce the number of weeds but will help to make a better seedbed. To a certain degree, yields are dependent upon the preparation of the seedbed. The young roots must get into immediate contact with the soil particles to insure the rapid growth of the young plant. Since it takes longer for sorghum plants to establish themselves than for corn, weeds have a better chance to start. For these reasons greater care is necessary in preparing the seedbed for sorghum than is usually given to corn.

SEED AND SOWING

Quality of seed.—Sorghum seeds are relatively small. The kernels are held between two short glumes which hold rather firmly even after being threshed. Usually a small proportion of the seeds are not free from the hulls (glumes) when marketed or ready for sowing. These are generally of poor quality and should be removed.

The standard weight of sorghum seed is 57 pounds to the bushel.

Good seed is the first requisite for a large yield. As with other crops, plump, well-filled, mature, sound, well-graded, uniform seed is conducive to best results. Sufficient seed should always be obtained to allow for thoro cleaning and grading. Home-grown seed needs careful cleaning to remove all chaff, sticks, and light seeds. Commercial seed is usually cleaned, but not always well graded. To overcome the lack of thoroly graded seed of high germination, a larger quantity per acre is often sown. This is not advisable. Seeding at the proper rate with good seed will give more satisfactory results. With the present high cost of labor it is not practical to plant thickly and then to thin the plants in order to obtain the proper stand.

Germination.—Testing sorghum seed for germination is vital in securing satisfactory crop returns. The seed contained in the hulls does not outwardly exhibit its relative value nor is it always possible to judge properly the value of thoroly shelled seed. Hence, the only accurate way to determine its vitality is by testing. It is frequently low in vitality. A germination of 90 per cent may be regarded as a high average.

Rate of seeding.—The rate of seeding in check rows will approximate two pounds to the acre. This will allow for from five to seven stalks to the hill, six stalks being regarded as the proper stand. For a small patch for home use it may pay to plant more seeds and thin the plants to the required stand. For drill-planting more seed is required. From four to six pounds is most frequently reported. but four pounds of good, well-graded seed should be sufficient. The plants should be about five inches apart in the drill row and should be evenly distributed in order to secure uniformity in maturity and, thereby, in the quality of the sirup. A special plate for the planter box can be made to drop with regularity.

Time of seeding.—The time when the seed may safely be sown will vary with the seasons. Sorghum seedlings are not vigorous; hence they must not be stunted by too early planting. Sorghum may be planted immediately after corn planting time. In Minnesota this will be from about May 15 to June 1. For home use the patch may be planted all at one time, but for commercial milling it is generally thought best to plant at intervals of ten days or two weeks. As weeds are a serious menace to the young plants, disking and harrowing should immediately precede the planting.

Method of seeding.—The method of sowing varies according to the conditions of the soil and plans for handling the crop. Two methods are used in Minnesota: the check and the drill row. These are exactly the same as with corn except that more seeds are used on a given area. The commonest and probably the best practice is to sow in drills so that the plants will be about four inches apart. Except for forage, sorghum is never sown broadcast. Great care should be taken not to plant the seed too deep. One inch is considered a good average depth, because the seeds are small and the seedlings are not vigorous. Unless care is taken, seed planted with a machine will be too deep. Some growers now plant with hand planters. They say they secure an even stand in this way without replanting, and hence have a crop which matures uniformly.

CULTIVATION

Cultivation for sorghum is like that for corn. Broadly speaking, the preparation of the seedbed may be regarded as cultivation. If this work has been well done, the work with the cultivator will be minimized and the need of hoeing probably obviated. Blind cultivation is not considered a great advantage in sorghum fields, except when weeds are started before the sorghum is up, and if the surface is packed or baked. If weeds get the start of the young plants before the sorghum is two or three inches high, it will be necessary to hoe the hills or rows or to replant. If close observation indicates that weeds are likely to get ahead of the sorghum plants, the field may be harrowed with a light slant-toothed harrow. The cultivator should never be run more than two and a half or three inches deep. Deep cultivation easily injures the root system and is unnecessary on a well-prepared seedbed. Type of cultivator is not important except as it may influence depth. The necessary work in killing weeds and creating a dirt mulch can be done with any of the modern cultivators.

The necessary number of cultivations will vary according to the prevalence of weeds and the tendency toward drought. Those who have observed sorghum culture closely say that more cultivation than is generally given corn will increase the yield.[5] Sorghum may be cultivated up to the time it puts out heads without damage to the crop. In dry seasons it is especially important to cultivate frequently.

HARVESTING

TIME TO HARVEST

The stage of growth at which sorghum may be harvested for sirup making is easily ascertained by inspecting the seed head. It has been observed that when the seeds are in or have passed the hard dough stage the canes are in the best condition for making sirup. The sugar content increases as the seeds become hard, and the more mature the cane the better it is for sirup making. Frost, however, is a factor which enters into the question. For this reason it is best under Minnesota conditions to start harvesting as early as possible, especially if there is a large amount of cane to handle. If harvested when the seed are in the earlier stages of maturity, the sirup is likely to have an unripe flavor and is very difficult to defecate. The composition at different stages of maturity is variable.

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[5] Bulletin 149, Minnesota Agricultural Experiment Station, p. 14, gives an account of results and cost of corn cultivation. (This bulletin is no longer available for distribution.)

TOPPING

The seed heads must be removed before the stalks are run into the crusher rolls. The exact manner of removing the tops will be governed by the manner of handling the canes in the field and at the mill. From eight to twelve inches of the stalk should be removed with the seed head, since the top joint of the cane contains very little sugar and a great deal of non-sugar substances. When small patches are grown, the topping may be done by hand with a knife as the plants stand in the field, or after the stalks are cut and bundled. Machines for removing the heads at the mill are discussed later.

It has often been recommended that the seed heads be removed from ten to fourteen days before maturity in order to increase the sugar content of the juice. Experiments at University Farm have proved that this gives no gain. The removal of the seed heads hastens the maturity of the juice, but no more sugar is formed than would be the case with the heads on. Then, too, the seeds are too valuable to waste by cutting before they are ripe.

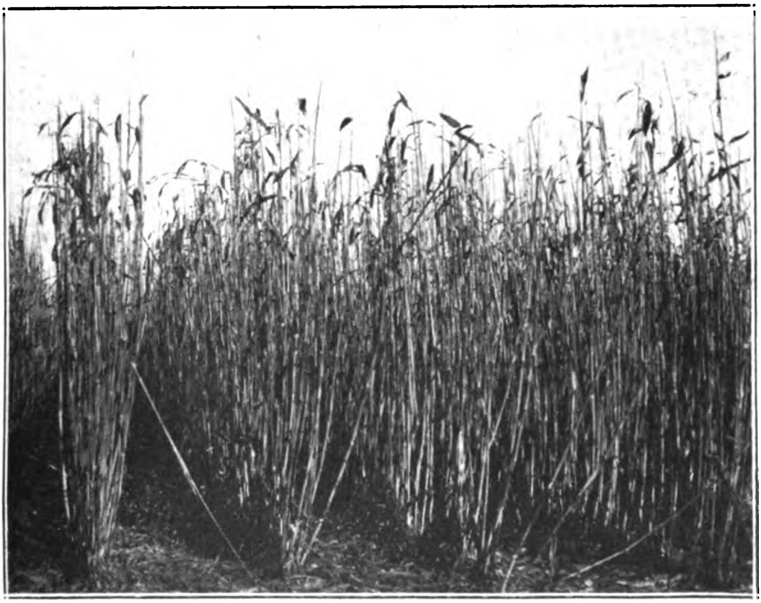

Fig. 9. Early Amber Sorghum Topped and Stripped Preparatory to Cutting and Hauling to the Mill

STRIPPING

For small mills the leaves should be stripped from the canes. This is done in the field while the cane is standing, using a stick or a pitchfork. For large, heavy mills the leaves may be left on, provided the cane is shocked for a few days so as partly to dry the leaves. Figure 9 shows a field of cane stripped. topped, and ready for cutting.

CUTTING

Cutting may be done with a corn binder or a self-rake reaper or by hand. The canes may be hauled to the mill while fresh, or left in bundles on the ground for three or four days, and then shocked and allowed to remain for ten days or two weeks without loss of quality, thus prolonging the milling season. At the mill the cane is usually ricked up like cordwood. (See Figures 13 and 14.) Close watch of the bundles, piles, or shocks will be necessary to prevent molding. A light frost in the field or slight heating in the rick is thought by some manufacturers not to injure the quality of the sirup, but the crop should be milled as soon as possible or the quality is likely to be impaired.

When lightly frosted, sorghum may be stripped, topped, and shocked without loss of quality or quantity of sirup, if this is done immediately. If it has suffered a heavy frost, it must be stripped and hauled to the mill at once, as the juice deteriorates very rapidly. If a frost is expected, the cane may be cut with the leaves on and left on the ground where it is considerably protected from the frost.

HARVESTING THE SEED

The quantity of available seed of Minnesota Amber cane has always been limited and insufficient to meet the demand. Those who raise sorghum should endeavor to save enough seed each year to last two years. There is a very good opportunity for a careful farmer in each county to raise sorghum seed on a commercial basis. A yield of from 10 to 20 bushels of clean seed can be obtained from an acre. The average price paid for commercial seed has been from 15 to 30 cents a pound and from $7 to $10 a bushel.

To save seed from the crop harvested for sirup, the best heads should be gathered as soon as convenient after the crop is cut. When topped in the field the seed head falls to the ground. The longer it remains on the ground the poorer will be the grade of seed. To secure good seed, the medium sized and ripest heads should at once be gathered, tied in small bunches, and hung in an airy place to dry. This method has the advantage that seed is saved from only the earliest maturing plants. This naturally produces an earlier strain. In saving seed from a special seed plot, the crop may be allowed to stand longer in order to be better matured. When the seed is dry it may be threshed, or it may be held until spring. In large quantities it can be threshed with a flail or threshing machine. For home use in small quantities it may be stripped by hand.

After the seed is threshed it should be carefully cleaned in a fanning mill. For first-class seed a grain grader will be found most useful. The grader separates on the basis of the weight of the individual seeds and makes a very uniform quality of seed.

Sorghum seed has a good feeding value, but the quantity produced in Minnesota is not sufficient to be of consideration for feeding livestock as is the seed of the non-saccharine sorghums raised in the southwestern states. Early Amber seed grown in Minnesota may be considered for a poultry feed.

USE OF BAGASSE

The majority of sorghum mills make no use of the bagassė. Reports of sixty-five men operating mills show that ten burn it, sixteen use it as fertilizer, ten use it for feeding livestock, thirty allow it to decay, two put it in silos, and seven use it for fuel.

The comparative analysis of bagasse from cane milled with the leaves on and of fodder corn is shown in Table V.

TABLE V

COMPARISON OF ANALYSES OF SORGHUM BAGASSE, CORN FODDER, AND CORN STOVER*

Kind	Dry matter in 100 lbs.	Digestible nutrients in 100 lbs.			Fertilizer constituents in 100 lbs.		
		Crude protein	Carbohydrate	Fat	Nitrogen	Phosphate	Potash
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Sorghum bagasse	62.1	0.3	36.5	0.5	3.2	...	...
Sorghum fodder	20.6	0.6	11.6	0.3	2.1	0.7	3.4
Dent fodder corn	21.0	0.9	12.2	0.4	2.7	...	...
Corn stover	59.5	1.4	31.2	0.7	6.1	3.8	10.9
Sorghum bagasse†	62.1	0.8	21.0	0.8	2.4	1.4	5.5

* From "Feeds and feeding" by Henry, 10th edition, except the last item.
† From analysis of Minnesota Amber made at University Farm.

The figures show that there is some value in the bagasse when the leaves are included. Stripped cane, however, gives a bagasse practically worthless as a feed. The larger mills can use it profitably for fuel, but the smaller mills not equipped for burning it should plan to use it for feed or as a manure.

METHODS OF HANDLING THE CROP

The culture and handling of sorghum, as practiced in Minnesota, is indicated in the summary of the reports obtained from farmers. (Table VI.) The variations in methods indicate that there has been no careful study devoted to the crop. In short, the farmer has desired the sirup and to obtain it secured seed and planted it without regard to the economic production of the crop.

TABLE VI
VARIOUS PRACTICES IN SORGHUM CULTURE IN MINNESOTA

Item	Total number reporting	Number reporting and differences in practice
Acreage	111	From ⅛ acre to 60 acres, an average of 4.13 acres each; 16, grow for forage
Mode of planting	117	79, drill rows: 36, checked; 1 both; 1 broadcast
Distance between rows	103	8 under 2 ft.; 32, 2 to 3 ft.; 36, 3 to 3½ ft.; 27, 3½ ft. and more
Number of stalks per hill	59	27, 3 to 5; 32, 5 to 8
Date of planting	106	34, May 1-10; 30, May 10-15; 33, May 15-31; 9, June 1
Kind of tillage	114	42, hoeing and cultivating; 49, "same as corn"; 23, only cultivation
Stripping off leaves	105	30, with hands; 64, with sticks; 6, with fork; 5, do not strip
Manner of harvesting	103	70, cut by hand; 33 with corn binder or mower
Use as silage	83	5, yes; 78, no
Reported injury when fed to livestock	79	71, none; 8, yes. "Dries up milk cows."
Difficulties met with in sorghum growing	111	91, none; 20, short season; 2, cutworms
Where manufactured	107	62, at custom mill; 45, at home
Yields received	22	From 3 to 15 tons cane; 96, 50 to 150 gallons per acre
Use of bagasse	65	10, feed it; 16, use for manure; 10, burn it; 30, dump it; 1, silo it; 7, use it for fuel
Save seed for own use	114	95, yes; 19, no.

SORGHUM FOR FORAGE

Sorghum may be used as a pasture crop for hogs, sheep, or cattle. The stock should be turned into the field when the plants are approximately two feet high. It is not, however, much used in this way in Minnesota, as corn is the popular fodder crop. They are considered about equal in quality. A few people, mostly dairymen near the larger cities, prefer sorghum fodder, silage, and soilage to that of corn. The great majority of farmers prefer corn, chiefly because sorghum is slower to start and harder to handle during harvest and good seed is harder to obtain. The rate of sowing for fodder is generally about three pecks (42 pounds) per acre in drills 42 inches apart. This makes a very fine quality of forage. It may perhaps better be regarded as a hay than a fodder. For soiling, the same rate of seeding may be used but the rows are frequently planted 24 inches apart. For the silo half a bushel of seed is used and planted in drills 42 inches apart.

When sown at the rate of three pecks per acre in 42-inch drills there are about forty-four seeds per foot. At the same rate in 2-foot drill rows there are about twenty-six seeds per foot. When sown for the silo at the rate of half a bushel (28 pounds) there are about sixteen seeds per foot. Obviously this is vastly more seed than is necessary in each instance. One seed per inch is all that can possibly grow to advantage. This would require not more than fourteen pounds, or about one peck, per acre. A crop produced from this rate of sowing is sufficiently fine for any feeding purpose. For silage eight pounds of seed is sufficient. It must be remembered that the reason for the excessively heavy rate of sowing is that the seed generally used is unnecessarily low in germination—60-75 per cent. When sowing only from eight to twelve pounds per acre it is necessary to know that the vitality of the seed is not less than 90 per cent.

In harvesting it is usually best to allow the bundles to lie on the ground for a day or longer in order to wilt. If set in shock immediately, it is likely to mold, especially under the band. Sorghum that has not first been allowed to wilt is likely to make soft, mushy silage, slightly acid; or the juice may ooze out, causing an offensive condition. It can not be stacked or ricked up as corn may after it is field cured. As a convenience for feed, a few loads at a time may be hauled and stood up against a fence or pole as a large shock. For soiling or pasturing, the cutting and feeding begin when the plants are about two feet high. If not pastured too closely a second growth will often develop.

When cut for dry fodder the shocks should be well set and firmly tied (see Figure 10) to prevent falling (see Figure 11) with a consequent loss in feeding value. In the presence of much moisture a fallen shock molds and decays readily.

The yield of sorghum will approximate that of corn, from 3 to 5 tons of dry fodder or from 8 to 15 tons of silage. The yield will be greater or less according to the season, the thickness of seeding, the soil moisture content, and the fertility of the soil.

Results obtained at University Farm show that when grown for forage Early Amber sorghum has a tendency to grow a little taller and a little leafier than Minnesota No. 13 corn and to yield more green forage and about the same amount of dry fodder (see Figure 10). Table VII gives analyses of the forage of sorghum and of Minnesota No. 13 corn. These show that the nutritive value of sorghum fodder slightly exceeds that of corn fodder. The samples were taken from the shocks as dry fodder on November 28, 1910. It is interesting to note that 1910 was exceedingly dry, less than half of the usual precipitation being received. The fall season was dry. The two samples showed 12.24 per cent more moisture in the sorghum than in the corn (see also Table V). They were cut at the same stage of maturity and otherwise treated exactly alike. This difference in moisture content clearly indicates the reason for the rapid heating and spoiling of sorghum when it is ricked or stacked.

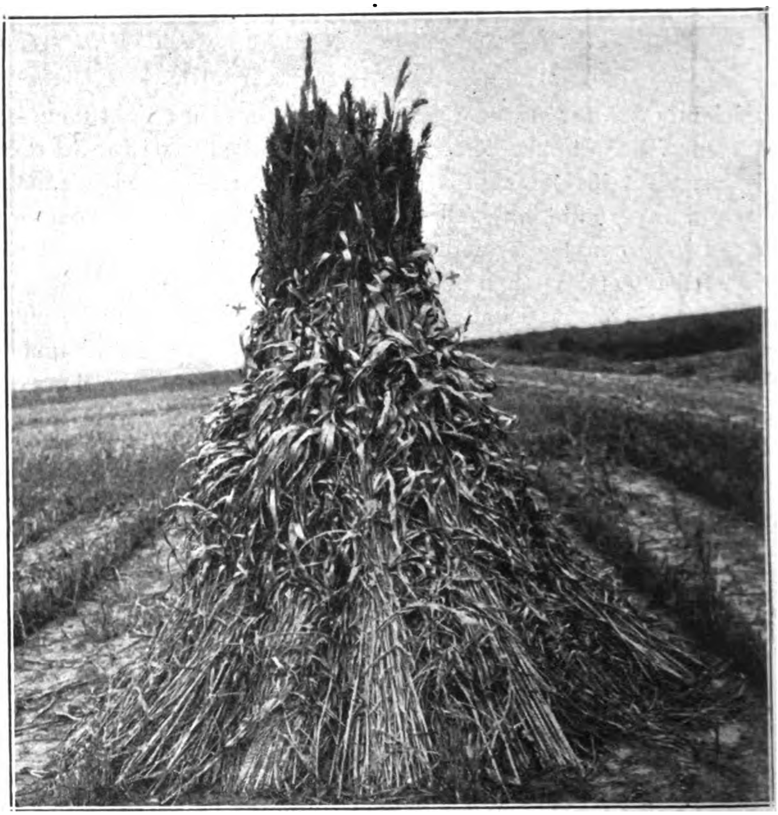

Fig. 10. A Well-Set and Properly Tied Shock of Sorghum
Note the position of the twine. Just below the seed heads is the place to bind a shock of sorghum.

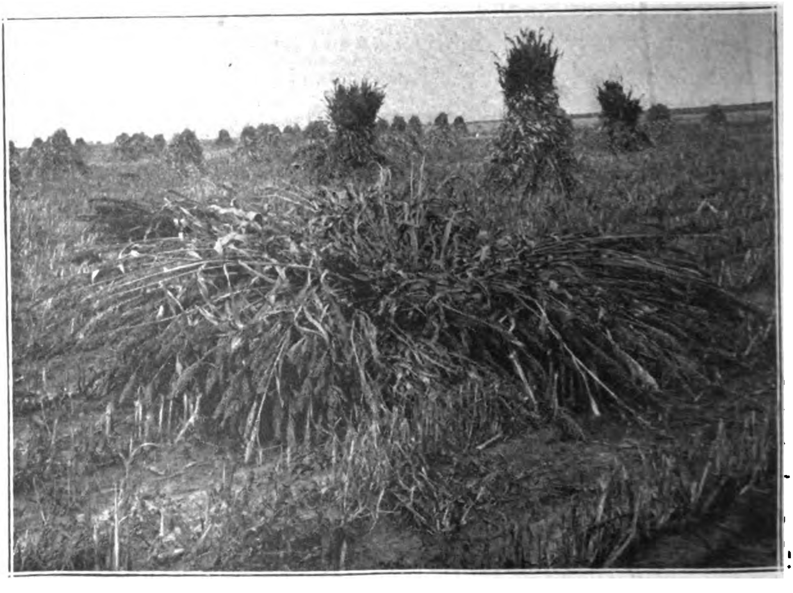

Fig. 11. A Shock of Sorghum That Was Poorly Tied
In this condition it would take but a few days to spoil the fodder or the sirup. Sorghum shrinks as the moisture is lost. If it is not tightly bound it will settle unevenly and thereby fall as shown in the picture. Rain also gets into the more open top, inviting mold and decay.

TABLE VII

COMPARISON OF ANALYSES OF SORGHUM FODDER AND CORN FODDER*

	Total moisture	Ash	Protein	Fat	Fiber	Nitrogen free extract
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Sorghum.........	39.61	5.73	9.15	2.42	27.10	55.6
Minn. No. 13 corn	27.37	7.05	7.14	1.95	29.16	54.7

*Analyses made by Division of Animal Nutrition, University Farm, St. Paul.

Do not feed young sorghum to cattle.—Young sorghum, and especially stunted growths, contains appreciable quantities of prussic acid, and has given considerable trouble in more southerly states by poisoning stock. Cattle are especially susceptible. Thrifty plants 2 feet high or more are perfectly safe to feed in reasonable amounts.

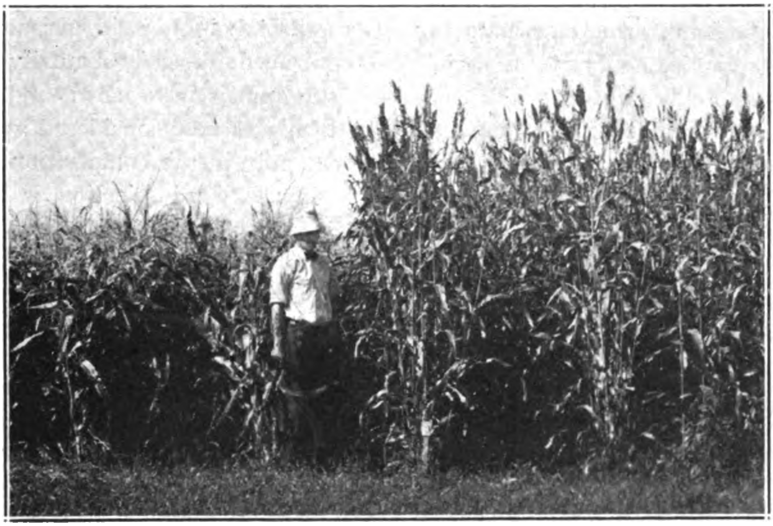

Fig. 12. Early Amber Sorghum and Minn. No. 23 Corn Grown for Fodder at University Farm in 1911

DISEASES AND PESTS

Sorghum is subject to two well-defined diseases: Blight, which is distinguished by reddish blotches on the leaves; and smut in two forms, which affects the seed head. Blight is more prevalent in wet seasons, but never seems to do appreciable damage. The smuts are not common in Minnesota, but sorghum growers should use great care to prevent their being introduced. There are two sorts of smut: (1) the head smut, which causes the entire head to blacken and to appear much as a mass of corn smut; (2) the grain or kernel smut, which is like the stinking or ball smut of wheat in that it affects only the seeds. The grain smut is the only one observed in Minnesota. The treatment for grain smut is identically the same as the treatment for cereal smuts.[a]

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[a] See Special bulletin 16, "Prevention of smuts," by E. C. Stakman, Minn. Agr. Exp. Sta.

The sorghum midge is somewhat of a menace in southern states, but does not infest the crop north of Missouri. Cutworms are sometimes reported as troublesome, but these usually occur where there is lack of attention to crop rotation and proper systems of soil culture.

IMPROVEMENT BY SEED SELECTION

The variety known as Minnesota Early Amber was originated fifty years ago by Seth H. Kenney, Waseca County, Minnesota. This marked the first work toward improvement. About 1912 he raised a strain which he regarded as better in some respects than the Early Amber and called it Early Rose. This is the only improvement of sorghum attempted in Minnesota. There is opportunity for improvement of uniformity in maturing, evenness in height, yield per acre, and quantity of sirup. Especially is there need for early maturity to better fit the crop to conditions where sorghum is now grown and to make it possible to grow it farther north than is now considered safe. Sorghum canes show great variability not only in the composition of the juice, but in the character of the plants. Seed selection is the first requisite for securing uniformity in quality and development of plants. Early maturing canes of high quality may be obtained with the aid of analysis of the canes, but this is expensive and hardly within the means of the individual or company manufacturing the sirup. However, it has been observed that certain external plant characters indicate to a fairly accurate degree the quality and maturity of the canes. This is reported by Wiley[7] as follows:

> "Special attention was given to studying the characteristics of the cane, showing that certain physical properties are associated with high percentages of sugar. By studying these properties carefully, it is possible for every farmer to go into his field and to determine certainly whether his cane is ripe or not. The most striking of these properties is found in the last joint of the cane bearing the seed head. By stripping the cane of its covering a yellow coloration will be observed extending more or less along the length of the joint as the cane nears maturity. By the extent of this coloration one is able to select the very best or the very poorest canes in the field almost as accurately as though tested by a polariscope. It is found that the cane which has the highest sucrose, lowest glucose, and highest purity has this coloration extending one-half the length of the joint. Should it be found to extend the full length, it shows that the cane has already commenced to deteriorate. On the other hand, should no coloration be visible, it shows that the cane is not yet mature. These observations have extended over one season of rather remarkable characteristics, and hence they may not prove equally applicable to a crop grown in a season with the ordinary amount of rainfall."

It has also been found that canes with suckers are not so good as those without. They ripen unevenly and generally later. The distance apart of the plants in the field has considerable effect on the sucker habit. In making selections, therefore, plants should be chosen that are free from suckers, are early ripening, and that show by the coloration of the upper joint that they possess the highest purity and sugar content. It should be remembered that for greatest improvement it is necessary also to practice the best methods of cultivation.

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[7] U. S. Dept. of Agr., Bur. Chem., Bull. 29. 1890.

The following plan is suggested for those who wish to raise their own seed in order to maintain purity, adaptability, and quality:

I. Grade out about five pounds of the plumpest and best seed of even weight from the best seed stock of Minnesota-grown Early Amber sorghum to be obtained. Test this seed for germination.

1. Plant this seed in hills 42 by 18 inches apart, using seven or eight seeds per hill, thus allowing for thinning later to five plants.

2. Thin when the plants are about three inches high, leaving the strongest five.

3. When the plants are heading out, cut off or pull out the heads of all undesirable plants—those that are weak, short, or stunted—or, on the basis of the average appearance, those that are below average.

4. When the seed on these plants are ripe, cut the heads with about ten inches of the stalk, tie in bunches of from five to ten, and hang in an airy place to dry. If the weather is bright they may be hung on the side of the barn or other building where they will dry rapidly. If cloudy or rainy, hang in a room or under cover.

II. The following year, in the early spring when time will allow, take down the bunches and pick out 100 of the best filled heads with well-matured, sound, and bright seed.

1. Strip the seed of each head separately, examine it carefully, and if satisfactory save it for planting. The seed of the selected heads need not be kept separate after passing inspection.

2. Clean and grade this seed thoroly and test for germination. Seed should germinate at least 90 per cent.

III. Plant and otherwise follow the plans for the special seed plot, as in I. The rest of the seed saved from the plot may be threshed in bulk, cleaned and graded and used to plant the larger fields, or sold. Following this plan for a few years will develop a strain that will be adapted to the growing conditions of the locality, uniform in height and in maturity. If other features are known to be desirable, a selection toward these will emphasize their value. Sorghum, being a freely open fertilized plant like corn, will readily cross with other sorghums. For this reason it is best to keep the special seed plot separated as far as possible from other sorghum, but it may be located along one side or in one corner of the main field if an isolated place is not available.

III. MANUFACTURE OF THE SIRUP

The process of manufacturing sorghum sirup is in brief as follows: The juice of the ripe cane with seed heads removed, but with or without the leaves removed, is expressed by passing it between heavy rollers. The juice is strained as it issues from the press and pumped into tanks for defecation. This is accomplished by heating it to the boiling point and then allowing it to settle, or by adding lime or other clarifying agents and then heating to the boiling point and settling. Instead of settling, the juice may be filtered. The clear juice is run into an evaporator where it is concentrated to the consistency of sirup, the scum being carefully removed as fast as formed. The finished sirup is passed through a cooler and is then ready for the containers in which it is to be sold.

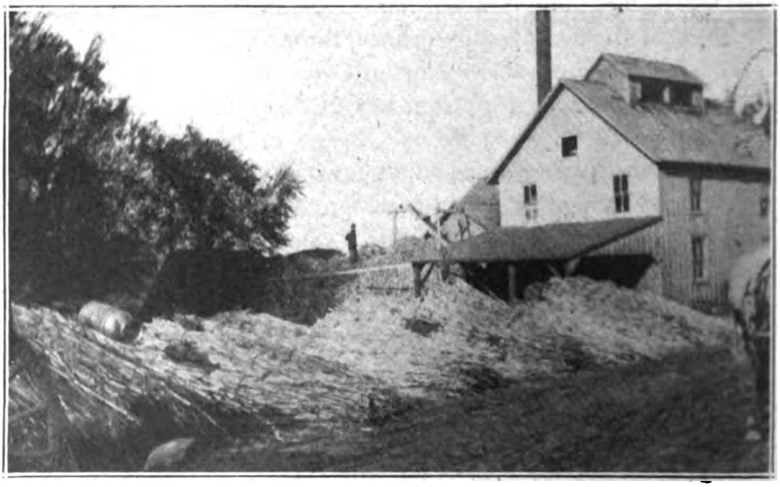


Fig. 13. Stripped Cane Piled in Front of the Factory Awaiting Grinding
Cane that has been partly cured in the field will keep in such piles for a week or more.

THE FACTORY

LOCATION

The guiding principles in the selection of the site for a sorghum sirup factory are similar to those for any other industry which is dependent on an agricultural product that must be utilized while fresh. Cane can not profitably be hauled from the field to the mill farther than three or four miles. Hence the factory should be located in the midst of a well-cultivated region from which a plentiful supply of cane can be drawn every year without the necessity of growing it on the same land in successive years. The factory should be located near a railroad so that a spur can be run to it. This will avoid expensive hauling of cans and other supplies to the factory and of sirup to the cars. As regards topography, any site will do which will give good draft for the furnace without excessive height of chimney.

THE BUILDING

A fireprooof structure is, of course, preferable, altho if the customary precautions are taken to isolate the boiler room and eliminate danger of fire, a frame structure does very well. A building 60 by 125 feet will accommodate the outfit for a 50,000-gallon factory, including the boiler-room, mill, evaporator, defecation tanks, sirup tanks, and space for filling cans. It is an advantage to have the crushing mill partitioned off from the rest of the factory in order to avoid the disagreeable noise. The evaporator should be placed directly beneath the ridge of the roof, so that a ventilator can be built into the latter to carry off the steam from the evaporator. The sides of this ventilator should extend down to within seven feet of the floor, forming a large shaft directly over the evaporator, in order to insure a good draft for carrying away the vapor. The sides of the building should be 16 or 18 feet high. This allows sufficient room for the various tanks to be elevated 7 or 8 feet from the floor, so that their contents can be emptied by gravity. Other details of construction and arrangement can be decided on only by reference to local conditions and demands.

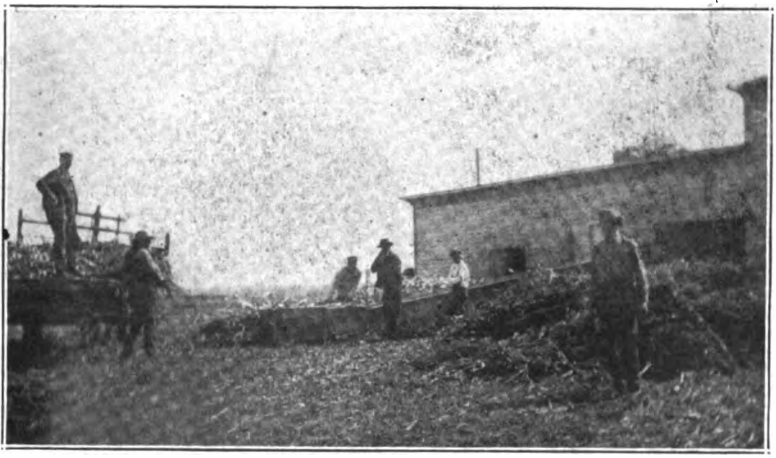


Fig. 14. The Cane-Carrier Outside a Large Sorghum Sirup Mill
A moving belt inside the trough feeds the cane directly into the crushing rollers. (Courtesy of Waconia Sorghum Mills, Waconia, Minn.)

MILLING MACHINERY

In general, the heavier the mill the greater the economy, as a larger proportion of the juice, and hence of the sugar, can be expressed. The three-roller horizontal mills are in use almost exclusively in larger plants, instead of vertical and two-roller mills. Following the experience of southern cane mills, it has been found advisable to employ two or three sets of mills in tandem. The first set has larger spaces between the rolls, and is designed to extract only the bulk of the easily expressed juice. The crushed cane then passes into the second and third mills, and is given a more severe pressing to extract the utmost possible amount of juice. Sometimes the pressed cane is sprinkled with water between the first and second sets. With such a system the bagasse is ready to be burned as it issues from the mill, thus saving all handling and drying of it. Also there is less strain on the machinery, as each set of rolls need not be used to the limit of its capacity. Some of the heaviest mills are fitted with a two-roll corrugated crusher which is designed to break up the cane somewhat, and to spread it evenly before it enters the pressing rollers. The weight and capacity of the mill and the power required are proportional to each other. Table VIII gives some of the specifications for pressing machinery.

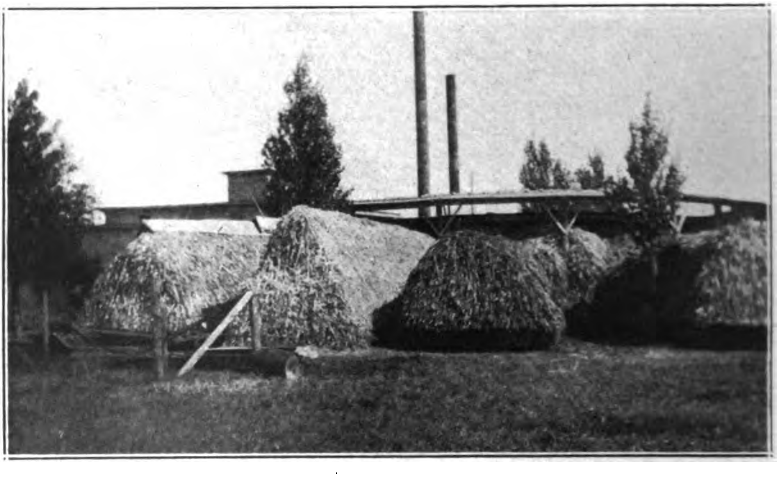


Fig. 15. Method of Stacking Bagasse

After standing in these piles till the following season, the bagasse is very dry and is easily burned. However, if sufficiently heavy mills are used, the bagasse can be burned green. (Courtesy of Waconia Sorghum Mills, Waconia, Minn.)

DEFECATION TANKS

Defecation tanks are made of galvanized iron reinforced with iron stays and bands, or of wood lined with galvanized iron. Their capacity is usually from 300 to 600 gallons, depending on the capacity of the evaporator. Three or four tanks are required in order to allow flexibility in the rate of pressing, defecating, and evaporating the juice. These tanks are elevated preferably 7 or 8 feet from the floor, so that the juice can be fed to the evaporator by gravity. The space beneath the tanks can be used for other purposes. Steam coils constitute the only practical method of heating these tanks, as a quick contrŏl of the heat is necessary. Lined wooden tanks can be constructed on the grounds quite cheaply. The copper or brass heating coils are arranged in two series, one on either half of the bottom, each series being fed separately from the main steam pipe. The pipes in the coil decrease successively in size, the first being about 2 inches. The bottoms of the tanks slant to a drain connected with the sewer for letting out sludge and wash water. Another outlet from the bottom conducts the juice to the evaporator. This outlet is fitted with some sort of movable pipe connection for removing the clarified juice continuously from near the surface of the liquid through the whole depth of the tank. The open end of the pipe is held between two parallel boards of the float which keeps the scum away from the outflowing juice.

EVAPORATORS

Three general types of evaporators are in use for concentrating sugar solutions:

(1) The arch evaporator. A shallow metal pan set over a brick or iron furnace (Figure 16). The juice flows in at one end, follows a zig-zag course along the pan while it is being evaporated by the direct heat from the furnace, and flows out of the other end as finished sirup.

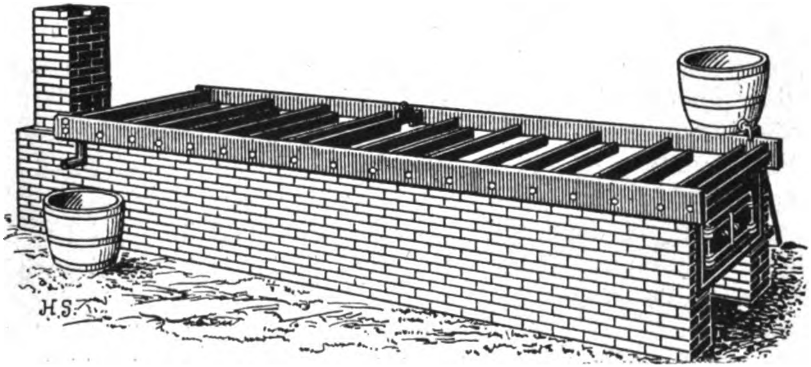


Fig. 16. A Pan Evaporator

These evaporators are limited in their capacity; the very largest are from 5 to 6 feet by from 15 to 18 feet, and have a maximum capacity of about 4,000 gallons of juice each 24 hours. Careful attention to the fire is necessary in order to secure a constant rate of boiling. These evaporators are inexpensive and are much used where wood is plentiful for fuel; where less than 12,000 gallons of sirup a season are made; and where steam is not used as power for pressing.

(2) The steam coil evaporator. Either cylindrical tanks or long, metal-lined troughs, the latter type being preferable (Figure 17). The

clarified juice enters at one end, passes over the steam coils along the first half of the evaporator, back along the second half, and then flows out of the lower end as finished sirup. The rate of flow can be regulated by changing the pitch of the troughs. These evaporators will concentrate from 4,000 to 10,000 gallons of juice in 24 hours. This is the kind of evaporator most commonly used in factories using steam power.

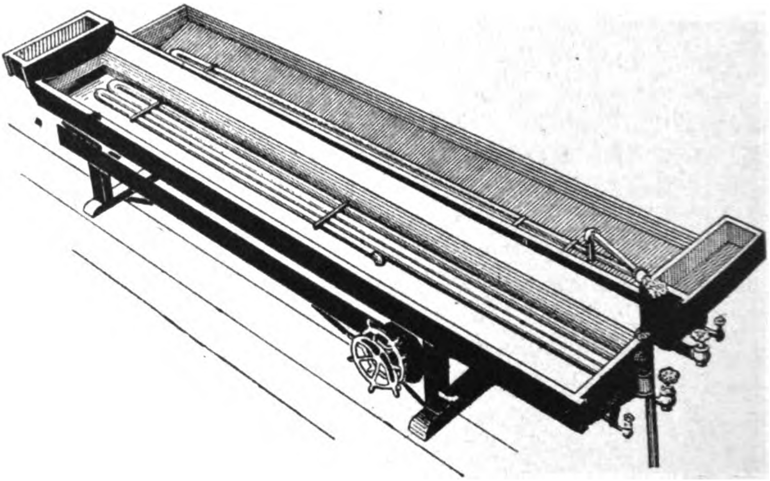


Fig. 17. A Steam-Coil Evaporator

(3) Vacuum pans. These are the same as are used in factories making granulated sugar. The principle underlying their use is that by boiling the juice in a vacuum instead of in atmospheric pressure, the temperature required for boiling is much lower, and hence the steam power used is much less. The power required to operate the vacuum pumps is far less than that necessary to boil the juice at the higher temperature. These pans are built in single, double, triple, and quadruple effects. Each pan or "effect" is connected with the others in such a way that the steam from the boiling liquid of the first is used to heat the second, and the steam from this the third, and so on. In each succeeding pan a higher vacuum is maintained, so that in spite of the lower temperature rapid boiling is accomplished. Juice can be evaporated with about half the power in a triple effect as in an open-coil evaporator. Vacuum pans are of very large capacity, hence they are considered for use only in factories where upwards of 16,000 gallons of juice in 24 hours are to be evaporated. Besides giving economy of fuel, these evaporators give a much higher quality of sirup, because of the avoidance of high temperatures in the last stages of the concentration. A single-effect vacuum pan has sufficient

capacity for a mill of 70,000 gallons output. and is the one specified in Table VIII.

FILTER PRESSES

Filter presses are machines for removing sediment and suspended matter from juices by filtering. The juice is forced through the filter by pumps under 40 pounds or more pressure. The press consists of a series of corrugated leaves over which heavy cloth is stretched. This gives many hundreds of square feet of filtering surface within a small space. The rate of filtration depends not only on the size of the filter press, but on the character of the sediment to be filtered. In sorghum juice the sludge is very gummy, and even when treated with generous amounts of filter cell (see page 43), it clogs the filter rapidly. A press having 500 square feet of filtering area should filter from 7,000 to 9,000 gallons of properly prepared juice in 24 hours, including the time occupied in cleaning the press.

MISCELLANEOUS EQUIPMENT

Furnace and boiler.—The furnace and boiler to be used in connection with a sirup factory are mostly matters of personal choice. The boiler should be adapted for burning bagasse direct from the grinding rolls, since a great economy in labor and fuel is thereby effected. The horse power to be developed will depend upon the combined demands of the press, the defecators, the evaporators, and the various heaters and pumps in the factory. Some of these specifications are given in Table VIII.

TABLE VIII

APPROXIMATE SPECIFICATIONS FOR THE MACHINERY OF SORGHUM SIRUP FACTORIES OF THREE DIFFERENT SIZES BASED ON 35 WORKING DAYS OF 24 HOURS EACH

	For factory of a season's capacity of		
	15,000 gal.	40,000 gal.	70,000 gal.
Gallons of sirup per day	430	1,100	2,000
Boiler capacity, horse power	100–200	150–300	200–600*
Grinding mills, number of rollers	3	6	6 or 9
Capacity per day, tons	30	80	140
Defecation tanks, number	2	3–4	3–5
Capacity of each, gallons	400	400	500–800
Supply tank for filter presses, gallons		600	800–1,000
Filter presses, number		1	2–4
Square feet of filtering area in each		400–700	500–700
Direct fire evaporators, area in square feet	60		
Gallons of juice per hour	140		
Steam coil evaporators, number required	1	1	2
Gallons of juice per hour each	140	360	300
Vacuum pan, single effect, gallons of juice per hour			500–800

*The great variation in horse power required in this case is due to the fact that if a vacuum pan is used less steam power is required for evaporation.

An economy in fuel and in time is gained by passing the fresh juice into a *heater* which is heated by exhaust steam. From this the juice enters the defecators already heated to from 150 to 200 degrees Fahrenheit.

Storage tank.—A covered storage tank for the finished sirup is a necessary part of the equipment, as it is impracticable in most factories to pack the sirup for shipment as fast as it comes from the evaporator. This tank is often arranged with the outlet about two inches above the bottom, so as to allow for settlings. In some cases two tanks are filled and emptied alternately to allow for better settling. If proper defecation is employed, however, there will be little or no sediment. The size of the storage tank will depend on the size of the factory and the rate of packing the sirup; it may be from a few hundred to a thousand gallons in capacity.

Header.—A header for cutting off the seed heads of the cane as it is being fed into the mill is a labor-saving device, since without it the heads must be removed by hand either in the field or as the cane is fed.

Miscellaneous equipment.—Such equipment as cane and bagasse carriers, strainers, sirup cooler, and pumps, need not be discussed. They are catalogued by many dealers for many lines of manufacturing and are not specifically different for sorghum sirup making.

EXTRACTION OF JUICE

There are a few simple and obvious rules to be followed in obtaining maximum efficiency from the cane mills. The cane contains from 70 to 80 per cent of water; all of which, however, can not be extracted. With a good mill and with stripped cane that is not too dry, 1,000 pounds of juice are obtained from a ton of cane; under very good conditions 1,200 and even 1,300 pounds can be obtained. The highest yield should be striven for by purchasing a sufficiently heavy mill and by feeding the cane so as to obtain maximum extraction. The cane must be very evenly distributed along the rolls. The proper depth of the layer can be determined only by trial. The space between the rolls is usually set at the factory at the optimum for that particular mill. For this spacing the greatest depth of cane must be found which will give the driest bagasse without straining the machinery, for the larger the amount of cane forced between the rolls the greater is the pressure developed and hence the higher the extraction of juice. When the best rate of feeding has been found, it should be adhered to as closely as possible. Care and skill are very necessary in proper feeding. The butts of the canes are usually fed first.

DEFECATION

IMPORTANCE

Probably no single factor in the manufacture of sorghum sirup affects the composition and quality of the sirup so much as the process of defecation. Good juices will often produce poor sirups if improper defecation is practiced; and poor juices can often be manipulated by proper defecation so as to produce sirup of acceptable quality. Furthermore, a greater uniformity in quality of sirup can be obtained if proper care is exercised in controlling the defecation.

There are many as yet unknown factors in this phase of sirup making, and the accepted practices of one mill may not be feasible in another mill. Each manufacturer should make a special study of the defecation process, institute every possible process and operation that will make for better sirup, and exercise the closest possible control over the method which he decides gives the best results.

Defecation of juice consists in the removal of non-sugar constituents by sedimentation, the object being, of course, to remove substances which would impart undesirable flavor and color to the sirup. The general methods of defecation are of three kinds: (1) that employing heat alone, (2) that employing heat and lime, and (3) that employing other chemicals. By any of these methods an insoluble sludge is produced, of which part sinks to the bottom of the defecator tanks and part rises to form a scum on the surface. This sludge is removable (1) by sedimentation, the clear liquid being drawn off and the sludge left in the tank, or (2) by filtration. Since either of these can be used with any of the methods of defecation, the latter will be discussed from the viewpoint of sedimentation, as this is the commoner method.

DEFECATION BY HEAT

The juice from the mills is pumped directly into the defecation tanks, or is first run through a heater heated by exhaust steam, so that the juice on entering the tanks is already warmed to from 150 to 200 degrees F. The juice is then heated to the boiling point. This brings to the surface a thick blanket of scum, consisting of bits of leaves and fiber, coloring matter, coagulated proteins, and other substances. The surface of the tank is watched carefully, and the moment the juice begins to boil, which is indicated by a few cracks appearing in the blanket of scum, the steam is turned off tightly. The juice is now allowed to stand for a time. The lighter sediment continues to rise, and the heavier settles to the bottom, leaving the greater part of the liquid clear and bright. The more time allowed for settling, the more complete it will be. At least ten minutes should be given. Then the clear juice can be drained from the defecator into the evaporator. The joints of the swing-pipe allow it to settle with the float as the surface of the liquid becomes lower in the tank. When within a few inches of the bottom, sediment begins to enter the pipe, and the tank is considered empty. The bottom juice, containing considerable sediment, is usually sent back into the stream of fresh juice from the press, and is redefecated in another tank. The heavy top sludge is washed into the sewer. If the bottom sediment is allowed to enter the swing-pipe to any extent, the resultant sirup is muddy and dark.

DEFECATION BY HEAT AND LIME

Sorghum juice is naturally rather strongly acid. In order to neutralize a part of this acid and thus produce a milder flavored sirup, milk of lime is added to the juice before defecating. The lime has the further effect of combining with certain of the impurities of the juice other than acids, and throwing them down as a part of the sediment. Thus the method of defecation by lime, followed by heat and by settling, as in the preceding method, is much more effective and satisfactory than the one by lime alone. Furthermore, it can be controlled very closely by determining the original acidity of the juice, and then adding the proper amount of lime to lower this acidity to the desired point. The details of this chemical control are discussed in the next section.

Experience has shown that it is preferable to add the lime before beginning to heat the juice. Somewhat more acid is neutralized per unit of lime added, and the resultant flocculent residue settles more readily. The disadvantage is that exhaust steam can not be used in warming the juice. It must be done quickly; hence live steam is required.

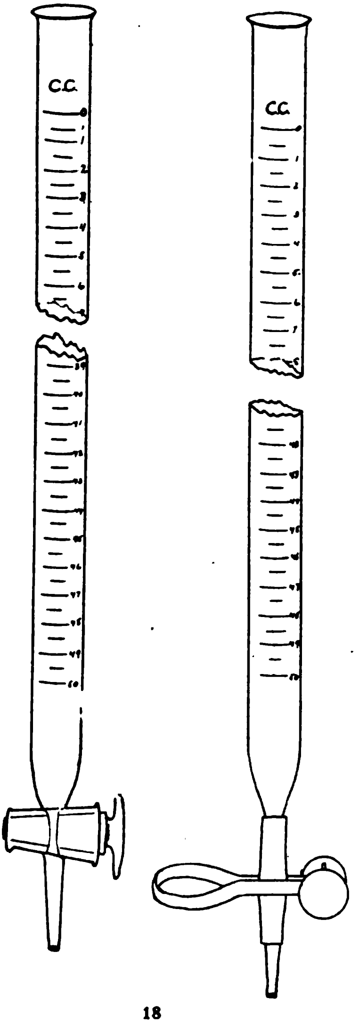
Control of the liming process.—The method of determining the acidity of juice is called titration. It is exactly the same method as is used in creameries for determining the acidity of cream. The following apparatus and supplies are needed (see Figures 18, 19, and 20):

1. *A burette stand and clamp* or some similar device for holding a burette in an upright position.

2. *A burette for measuring alkali* may have a glass stopcock or be fitted with a rubber tube and pinchcock. The latter is cheaper. In the former, the glass stopcock is likely to stick fast and break, altho it is a little more handy to operate.

3. *A pipette* of 50 cubic centimeters' capacity for obtaining samples of the juice. It is more convenient than a dipper, because the tip can be thrust into the liquid below the scum, and the exact amount of juice obtained by applying suction to the top of the tube and filling it to the mark on the stem.

4. *A wide-mouthed bottle,* or a mason jar of *white* glass, in which to conduct the titration of the juice. A still better container is an Erlenmeyer flask, obtainable through a druggist.



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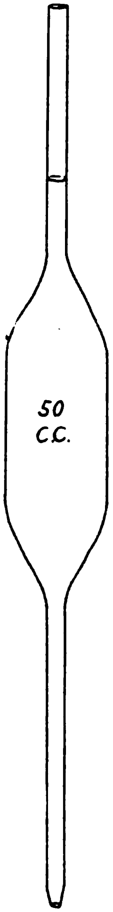

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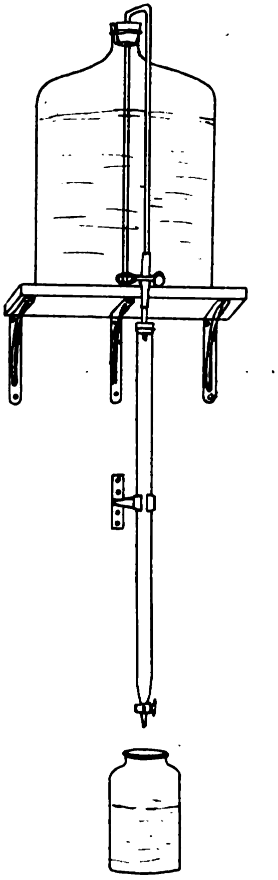

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Fig. 18. Two Types of Burettes Used in Measuring the Alkali in the Titration of Juice

Fig. 19. Pipette Used in Measuring the Sample of Juice to be Titrated

Fig. 20. Outfit for Titration of Juice

This is assembled in convenient form, with the bottle of standard alkali on the shelf supplying the burette by a siphon. The juice to be titrated is in the bottle below.

5. *Standard alkali.* This is of the strength known as one-tenth normal, and can be made only in a chemical laboratory. It is obtainable from creamery supply houses, from chemical laboratories, or from pharmaceutical houses. It must be kept stoppered, as it becomes weaker on exposure to the air; also, care must be taken that no water or other outside substance contaminates it, as it is an exact solution and its strength must not be changed.

6. *A 4 per cent solution of phenolphthalein in either wood or grain alcohol.* Denatured alcohol can not be used. Phenolphthalein is a dye, colorless in acid but bright crimson in alkali. It is used to indicate the change from an acid to an alkaline condition during the titration of the juice.

7. *Milk of lime.* This is made up in barrels or tanks, as large quantities of it are used. A convenient method of preparing it is to slake fresh quicklime of the best quality in enough water to form a thick paste, then to dilute this paste to a density of 15 degrees Baumé. It must be thoroly stirred before using; hence it is convenient to have this milk of lime in a covered tank of from 20 to 100 gallons' capacity and equipped with a power-driven stirring paddle.

8. *A three-gallon measure* for adding the milk of lime to the juice. The acidity is determined as follows: The tank of juice is thoroly stirred, the pipette is filled with juice and then drained into the titrating flask or jar. The flask is filled two-thirds full of clean water (preferably hot) in order to dilute the color of the juice. The burette is filled with alkali to the zero mark, after taking care that the stopcock (or the rubber tubing) is free from all air bubbles and is completely filled with the liquid. About a fourth of an ounce of the phenolphthalein indicator is added to the flask. Then the latter is held under the burette, and alkali slowly added while the contents are rapidly shaken. When the contents of the flask have become a well-defined pink instead of the natural green or brown, the "end-point" has been reached and no more alkali is added. The amount of the standard alkali required to produce this pink color in the 50 cubic centimeters of juice is a measure of the acidity of the juice; the higher the acidity, the more the alkali required. The number of cubic centimeters of alkali required is called the "degree of acidity." It varies from about 10 to 20, being higher in the more immature juices.

Sufficient lime is now added to the tank to reduce the acidity of the juice to 6 or 8 degrees. If it is reduced below this the sirup will be still more mild in flavor, but it will darken considerably in color. If the juice is made alkaline it becomes very dark and has a bitter, unpalatable flavor, and fresh juice must be added to bring the acidity back to the proper point. The amount of lime needed, of course, depends on the strength of the lime solution and the acidity of the juice. If the lime has been made according to the above formula, and if the acidity is close to 15 degrees, about 3.5 quarts of the milk of lime for each 100 gallons of juice will reduce the acidity to *about* 6 degrees. After adding the lime, thoroly stirring it into the juice, and allowing a few minutes for it to act, the acidity should be determined again. After some practice, a table can be compiled which will give the amount of lime of the strength in use in that factory to be added to the contents of the particular size of tank employed in order to reduce juices of various degrees of acidity to 6.

DEFECATION BY OTHER MEANS

Phosphoric acid or *phosphates* are sometimes recommended in connection with defecation by lime. When a solution containing a phosphate is added to one containing lime, or vice versa, the two chemicals unite to form a heavy, gelatinous precipitate, which settles to the bottom, absorbing and carrying with it considerable coloring matter and other non-sugar impurities. It is used very extensively in the clarification of sugar-cane juices. It appears to be of less value in sorghum defecation, however, since with cane juice its success depends on liming to alkalinity, adding phosphoric acid to 1 or 2 degrees of acidity, and then removing the sediment by means of a filter press. In most sorghum sirup plants this procedure can not be followed, and the addition of smaller amounts of phosphate and lime seldom produce marked improvement in the defecation.

Filter cell, a light, porous, siliceous material, similar to infusorial earth and fullers' earth, when added to defecating juice with any of the above methods, absorbs a considerable quantity of impurities and settles readily to the bottom, aiding very materially in clarification. It is used at the rate of from 3 to 5 pounds per 100 gallons of juice, and costs but a few cents a pound. It adds no taste of its own to the sirup. If a little of it gets into the swing-pipe, it practically all comes out in the skimming. The use of filter cell could well be adopted by more factories.

Clay. Various kinds of clay have been advocated from time to time for aiding in the settling of juices. Clay of the proper kind is helpful, but it is difficult to obtain. Since filter cell performs the same work, and is easily obtained, it is recommended in place of clay.

FILTRATION

When filter presses are used for removing the sediment, several procedures can be adopted. The whole juice, with all the sediment, can be filtered after defecation; the semi-clear juice with only the bottom sediment from the defecation tank can be filtered; or the semi-clear juice can be drained into the evaporator as described above, until the bottom sediment is reached, then this sediment alone filtered, after a sufficient quantity of it has been collected in a separate tank. The second procedure has been found most satisfactory.

The details are as follows: The juice is defecated by means of lime in the usual way, with the addition of 5 or 10 pounds of filter cell for each 100 gallons of juice. Only a few minutes need be allowed for the top scum to collect before the juice is emptied into a special tank for feeding the press. In this tank the juice is treated with from 10 to 15 pounds more of filter cell for each 100 gallons of juice. The filter cell and the gummy sediment form an open, porous cake on the cloths of the filter press which retards the clogging of the cloths. The feeding tank is provided with a power-driven paddle which prevents the filter cell from settling, and causes an even suspension of it to flow into the press.

The system of tanks in the factory should be such that sufficient juice can be accumulated to run the press continuously until the cloths are so clogged that they filter too slowly for economy in time. If the flow through the press is interrupted, a cloudy filtrate is very likely to result. The depth of press cake that will accumulate on the cloths will depend on the gumminess of the sediment and the amount of filter cell used. A press of 500 square feet of filtering surface should take care of 1,500 or 2,500 gallons of juice before being cleaned. This will usually take from one to two hours. Thus the necessary capacity of mill, defecation tanks, filter press, and evaporators must be adjusted so as to make possible a regular and unified operation of the whole plant. Specifications and directions are furnished by the manufacturers to fit each machine.

A modification of the above process which often gives a clearer sirup is to conduct the juice which has been clarified by settling into the evaporator, concentrate to about half, then pump it through the filter press and continue the evaporation to the end. The lime salts of malic and citric acids precipitate out only after the juice has been boiled for a while. If the filtering is done previous to this, these salts will cloud the sirup and even produce a sediment in it. Filtration after they have formed removes most of the possibilities for cloudy sirup.

EVAPORATION

The main points that must be kept in mind in order to secure successful evaporation with any type of evaporator are: (1) The juice must be concentrated as rapidly as possible without scorching; (2) the scum must be removed as thoroly as possible; (3) the finishing point of the sirup must be correctly determined and maintained uniform day after day.

DIRECT-FIRE EVAPORATORS

With a direct-fire evaporator an even fire must be carefully maintained, since the juice flows in at one end at a regular rate, and should follow the course of the pan and flow off as finished sirup also at a regular rate. To secure this regularity, an even fire is a necessity. Careful skimming with perforated scoops is carried out constantly. The depth of juice in the pan should not be more than an inch and a half, in order that the juice may follow the course of the pan in as short a time as possible.

The scale that gathers on the bottom of the pan must be removed at frequent intervals, since it insulates the heat and thus retards evaporation. This is a laborious process. It can be made easier by immersing the coils in a warm 3 per cent solution of hydrochloric acid for ten or fifteen minutes. If the evaporator can be spared for that length of time, the acid can be run into it, the steam turned on for a moment, and, after the scale is loosened, the acid drained or pumped into a container and used again. *This acid treatment can be used only on copper utensils;* it will very quickly corrode galvanized iron.

STEAM-COIL EVAPORATORS

The great advantage of steam-coil evaporators is the uniform degree of heat with practically no liability of scorching. Also, they are so constructed that the foam and scum naturally work toward the outer edge of the trough where the boiling is less violent, and can easily be completely removed.

VACUUM PANS

Since the operation of vacuum pans is described by each manufacturer for the particular machine involved, general directions in this place would be useless. As has been stated, these pans are economic and practical only in very large factories with outputs of 60,000 gallons or more per season. Since by their use high temperatures are avoided, the resultant sirup is light in color and very clear.

FINISHING POINT OF THE SIRUP

There are several methods of determining the finishing point of the sirup: judging by the appearance of the bubbles, the specific gravity by means of a Baumé spindle, and the boiling temperature. The first named is uncertain, unscientific, and depends entirely on the experience of the operator. The Baumé spindle is a hydrometer designed to give the specific gravity of liquids on an arbitrary scale of 0 to 50. It is floated in a cylinder full of the sirup, and the density read on the stem. The disadvantage is that it does not give a continuous determination of the concentration of the sirup. However, with a thermometer fixed in the finishing end of the evaporator in such a way that the bulb is entirely immersed in the boiling sirup without touching the bottom or sides of the pan, the density of the sirup can be ascertained at all times by simply reading the boiling point, since the temperature of a boiling sugar solution increases with increasing concentration. 221 degrees F. is the boiling point of a sirup that weighs 11½ pounds to the gallon and has from 70 to 75 per cent of total solids This is the standard density for commercial sirups. This boiling point, however, changes with different batches of juice; hence it is advisable to check it from time to time by means of the Baumé spindle. The sirup should have a density of 38 degrees Baumé when cold, or 35 degrees while hot.

TREATMENT OF FINISHED SIRUP

CLARIFICATION

The finished sirup is more or less cloudy, owing to suspended matter, in spite of all precautions in defecation and skimming. Many attempts have been made to clarify this sirup by filtration through flannel, felt, or other media, just as maple sirup is treated, but sorghum sirup, even when hot, is too viscid because of the gummy substances contained in it. In many cases, if the sirup is allowed to settle, considerable sediment will sink to the bottom of the tank and the clearer sirup can be drawn off above it. Therefore it is always best to provide adequate storage room for the finished sirup, so that several days can be allowed for settling before the sirup is packed in the final containers. There are many styles of such tanks on the market. Most of the cloudiness of sorghum sirup can not be removed by sedimentation. since it is due to particles which are too small to settle. There is no means of removing them. If the defecation has been carefully performed, and especially if filtration has been employed and thoro skimming practiced, the sirup will not be conspicuously cloudy. In the writer's experience, the only way to obtain perfectly clear sirup is to defecate at a boiling temperature, filter, and then evaporate in a vacuum pan at a temperature 20 degrees or more below the boiling temperature. A very bright, light-colored, and clear product can be obtained in this way.

COOLING

The sirup must be quickly cooled as soon as it leaves the evaporator. as it darkens very rapidly. To accomplish this, it is run through a cooler before being pumped to the settling tanks.

PACKING FOR MARKET

Sorghum sirup is packed in a great variety of containers. In the smaller mills, where custom work is done, a good deal of the sirup is taken away by the cane growers in kegs, jugs, milk cans, and other containers. When the sirup is prepared for the public market it is usually packed in 1-, 2-, 5-, or 10-pound tin cans of various styles. When the sirup is to be sold to blenders to be mixed with corn sirup, it is usually packed in barrels. If ordinary precautions of cleanliness are observed by storing the sirup in tightly covered settling tanks, using air-tight cans, and taking care that the cans are as full as possible, there will be very little trouble with spoilage. It is desirable to scald the cans with steam before filling with sirup, altho many factories in the cooler sorghum regions do not take this precaution and have very little trouble with spoilage. The packing of the cans with hot sirup would be a desirable procedure were it not for the darkening in color which always results from slow cooling.

CHARACTER OF SORGHUM SIRUP

CHEMICAL COMPOSITION

Sorghum sirup contains all of the substances which were in the original juice, minus those which were removed by defecation and by skimming. The latter processes remove mostly proteins, acids, and coloring matter. The proteins are coagulated by the heat and are removed in the sludge in the defecation tank. The acids are neutralized by the lime and mostly converted into their insoluble lime salts. Part of these insoluble salts is removed in defecation (and in filtration where the latter is employed), part rises to the surface during evaporation and is removed in the scum, and part remains in the finished sirup and is more or less removable by settling. The coloring matter, together with little-known substances that are connected with the flavor, are removed also by the liming, and are aided in their precipitation by the addition of the filter cell mentioned in the section on defecation. It is readily seen that the removal of these various non-sugar substances greatly improves the color and flavor of the sirup. The sirup does, however, contain some unneutralized acids, principally tartaric.

The sugars that are found in sorghum sirup are sucrose (cane sugar), dextrose (grape sugar), and levulose (fruit sugar). The last two are usually classed together as "reducing sugars." They are the non-crystallizable sugars, whereas the sucrose is the one which so often "sugars out" from heavy sirups. Besides these sugars, starch and dextrin are also present to the extent of 3 or 4 per cent, and are usually classified as gums. Sorghum sirup is rather high in mineral matter, the ash being usually from 2 to 3.5 per cent.

Table IX gives the analysis of sorghum sirups from various localities and produced by various methods. It may be well to point out some of the facts that are shown in these figures.

(1) There is a direct relation between the amount of lime used in defecation and the acidity of the sirup. If the juice is limed to 6 degrees of acidity, the resultant sirup will have an acidity of about 0.7 per cent.

(2) The proportion of sucrose to dextrose in the sirup depends mainly on two things: the maturity of the cane and the acidity during defecation and evaporation. As the cane matures, the sucrose increases and the reducing sugars decrease in amount. The effect of boiling sucrose in the presence of acids is to convert it into dextrose and levulose, a change which is called inversion; hence the higher the acidity during defecation and evaporation the lower will be the sucrose and the higher will be the reducing sugars (dextrose and levulose) in the sirup. This is shown by the data in the table. There is no loss in sweetness by this inversion, in fact, there is a slight gain; and the less sucrose there is in the sirup the less tendency will there be for the sirup to "sugar out." In most cases there will be no trouble of this kind if the sirup is not concentrated beyond the point specified in the section on evaporation; the presence of the gums prevents crystallization. This was one of the facts which caused the abandonment of sorghum as a source of granulated sugar. If the juice is from mature cane and is very pure—that is, contains low percentages of non-sugar substances—and trouble is had with crystallization, it has been found feasible to invert part of this sucrose by adding one pint of 5 per cent hydrochloric acid to each 100 gallons of juice in the defecator, allowing it to act while the tank is being heated. When the temperature reaches about 170 degrees F., the juice is limed and the defecation continued as usual. The trace of hydrochloric acid is completely neutralized by the lime. It is not often that this process is necessary.

(3) The amount of mineral matter is proportional to the lime used. This is due to the fact that not all of the lime is converted into insoluble compounds and thus removed in the defecation. A portion remains as soluble lime compounds and thus raises the content of mineral matter. There is no particular objection to this mineral matter, as it is harmless, and the slight effect it may have on the flavor is greatly offset by the improvement in flavor due to the lime treatment.

(4) The standard density for sorghum sirup is such that there is about 75 per cent of total solids. If these are much above 80 per cent, the sirup is very thick and viscid, and is almost sure to "sugar out." Then, too, it is not economy to produce such heavy sirups, as they do not command a higher price.

TABLE IX
COMPOSITION OF VARIOUS SAMPLES OF SORGHUM SIRUP

Source of sirup and method of defecation	solids	Sucrose	Reducing sugars	Acids (as tartaric)	Mineral matter	Gums
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Minnesota; heat alone	76.2	38.7	30.9	1.06	2.9	2.7
Minnesota; moderate amount of lime used*	76.7	42.2	27.6	0.77	3.2	3.0
Minnesota; limed almost to neutrality	73.4	40.4	27.1	0.62	3.4	1.9
Georgia; juice boiled directly without any defecation†	74.6	40.0	28.4	0.79	2.8	4.0

* Compiled from paper by Anderson. Jour. Ind. and Eng. Chem., 9:12 (1917).
† From paper by Jordan. Jour. Ind. and Eng. Chem. 9:758 (1917).

COLOR

Sorghum sirup may be dark brown or almost black in color, it may be a light amber, or it may have a greenish cast. The second is the color to be striven for by the manufacturer, since a light color enhances its value on the market. The dark color may be brought about by any one or several of the following conditions: (1) Too much lime, (2) long, slow boiling, (3) slow cooling of the sirup after coming from the evaporator, (4) scorching during evaporation, (5) juice relatively low in sugar, and thus high in impurities. The more acid the juice is when evaporated, the lighter in color will it remain. Since, however, the flavor depreciates with higher acidity, a desirable balance between the two extremes must be selected. For this reason, an acidity of 6 degrees is recommended. These facts also show the necessity for lime defecation and for chemical control over that defecation, if uniformly high quality sirup is to be produced.

The greenish color of some sirups usually results from fresh green cane and a rather high acidity. If juice from green cane is reduced in acidity to the proper degree, much of the greenish color will become brown. The best way to avoid this greenish color, however, is to allow the cane to become partially dry in shocks or on the ground before it is milled. Much less of the green coloring matter is extracted in this way. This is especially true when the cane is milled with the leaves on. The leaves must not be too dry and brittle, however, else they will be ground up into fine particles which are not completely removed during the subsequent treatment, and the sirup will be cloudy.

FLAVOR

There is a characteristic flavor to sorghum sirup that is different from that of any other sugar product. It may vary from a mild, slightly acid flavor enjoyed by practically all users, to a strong, sour, biting taste, enjoyed only by those who have become accustomed to it. Sirup produced for the general market must be rather mild without losing at the same time the characteristic sorghum tang. The flavor depends mainly on the maturity of the cane and the character of the defecation. Sirup from immature cane is poorer in flavor, since the juice is relatively high in non-sugar substances, and these can not be removed by defecation so successfully as from mature juice. Successful defecation consists in reducing the acidity to the proper degree, and coagulating by means of lime and heat as much as possible of the substances which will impart undesirable flavor to the sirup. Careful skimming also plays an important part in the production of well-flavored sirup.

USES

Most of the sorghum sirup that passes through the general market channels is used as a table sirup or in cooking. In the latter case it is substituted for cane-sugar molasses in most recipes. Another use which of late years has been demanding considerable sorghum is that of blending with corn or glucose sirup. The latter alone is rather flat and insipid; the sorghum alone is not relished by some people unless it is very mild; but a blend of 60 parts corn sirup with 40 parts sorghum sirup has been in considerable demand. When sorghum is to be sold to blenders, it should not be limed below 9 degrees acidity, since a stronger flavored sirup will be required in less amount, and the sorghum is the more expensive component of the blend.

IV. ECONOMIC CONSIDERATIONS

YIELDS

From 6 to 15 tons of cane per acre can be grown. Where it is cultivated as a special business for supplying a factory, and care and judgment are exercised in growing it, from 10 to 13 tons per acre are the rule, and in good seasons 18 tons are not unusual. From 9 to 20 gallons of sirup per ton are obtained, with the average of 14 gallons, depending on the degree of extraction of the juice and on its sugar content. Thus the average yield per acre under normal conditions is from 150 to 200 gallons, altho this may vary from 90 to 300 gallons.

From 10 to 15 bushels of seed per acre are produced by the sugar sorghums, which is lower than the yield of the grain sorghums. The seed constitute a by-product that is well worth the labor of harvesting. It is usually given a rating of about 85 or 90 per cent that of corn, as regards both feeding value and money value.

COST OF MANUFACTURE

Under this heading must be discussed both the cost of producing the cane and the cost of making the sirup. The cost of growing sorghum cane is about the same as that of corn up to the stage of harvesting, which in 1918 was between $20 and $25 per acre. This includes harvesting and shocking with the leaves on, but does not include hauling to the factory.

The method of harvesting, and hence also the cost of harvesting, will depend largely on the method of handling the cane at the factory. Usually the seed heads must be removed in the field by hand. One man can head about three acres in a day, if the heads are simply left on the ground. If the heads are removed at the mill by machinery, this cost item is eliminated. Where the cane is stripped of leaves, headed, cut, and bundled by hand, one man can not cover more than three-fourths of an acre a day. This method, however, is seldom followed in large mills. Where the entire cane is cut and bundled by a corn binder for the large mill, the labor is the same as for corn. It is thus very evident why the cost of harvesting cane for a large mill is about one third of that for a small mill.

In manufacturing the sirup, the labor is again the important item in cost, since on a small scale, where a horse sweep or small engine for extracting juice and direct-fire evaporators requiring constant attention are used, the amount of labor expended for each unit of product is far greater than where machinery does most of the work. And like all other manufacturing operations, the larger the plant the smaller is the unit cost of production.

It is thus very evident why small-scale production of sorghum sirup has lost favor. Careful estimates show that the total cost of producing sorghum sirup in a mill of a capacity of 1,000 gallons per season in 1918 was about 75 cents per gallon; in one of 20,000 gallons capacity, about 51 cents; and in one of 70,000 gallons capacity, about 46 cents. The itemized account by which these figures were arrived at is presented in Table X. The first part of the table shows the actual cost of producing the cane. To this must be added a profit to the grower, which brings the cost of the cane to the manufacturer up to about 33 cents per gallon of sirup.

METHODS OF PAYING FOR CANE

Since cane varies considerably in quality, especially in maturity and in content of sugar, it is very important that a system of payment for cane at the mill should be followed which will be equitable to all persons concerned. The value to the manufacturer of a ton of cane depends on (1) the amount of trash (leaves and seed heads), and (2) the percentage of sugar in the juice.

The leaves of fresh cane constitute about 15 per cent of the weight of the whole plant; of shocked and partly dried cane, from 8 to 10 per cent. The seed heads constitute about 14 per cent of fresh cane, and about 11 per cent of shocked cane. The juice of Minnesota Amber cane usually contains from 9 to 16 per cent of total sugars, depending upon maturity, weather, soil, and other factors. It is evident, then, that an equitable price for cane will depend largely on its condition and its composition when it is weighed at the mill.

TABLE X
APPROXIMATE COST OF SORGHUM SIRUP PRODUCTION IN MINNESOTA IN 1918

Cost of cane delivered at mill	Size of plant		
	1,000 gallons	20,000 gallons	70,000 gallons
Growing the cane, per acre	$18-$20	$18-$20	$18-$20
Harvesting	5-10	2-4	2-4
Average net cost per gallon of sirup to the grower at 120 gallons per acre	0.21	....	....
Average net cost per gallon of sirup to the grower at 160 gallons per acre	....	15	15
Profit to the grower, per gallon of sirup	0.12	0.12	0.12
Cost of manufacture of sirup			
Fuel and supplies, per season	$150-$225	$800-$1,200	$2,500-$4,000
Labor	150-200	1,500-2,500	2,500-4,500
Depreciation and upkeep, per season	40-70	800-1,200	1,600-2,500
Average cost per gallon of sirup	0.42	0.18	0.13
Total cost to the manufacturer, per gallon	0.75	0.45	0.40

The oldest method, and the one that is still followed to some extent, of determining the price to be paid for a given batch of cane, is to mill each batch separately, and then pay for it on the basis of the amount of juice obtained and its density. This involves considerable labor in stacking each farmer's cane separately and in keeping records. According to the old plan of custom work in the small mills, each batch was also evaporated separately, and then the grower received the sirup from his own cane or was paid a certain rate per gallon for it. These methods have the advantage of being perfectly equitable, since the grower of poor or of good cane is paid accordingly.

Another system is to pay a flat rate per ton for all whole cane, and another flat rate for all stripped cane, ignoring any variation in composition that occurs in the different batches. This method is simple to operate and in the long run is fairly equitable, since any one grower is likely to have both good and poor batches of cane, and the average will be paid for justly.

The most exact and at the same time the most feasible system to be followed in large mills is to mill small representative samples of each grower's cane in order to obtain an average sample of the juice, then pay for the cane on the basis of the sugar contained in the extractable juice, as measured by the Baumé hydrometer. A small mill, capable of expressing at least 60 per cent of juice from six or eight stalks of cane at a time, is set up in a convenient place for obtaining the test samples of juice. Each load of cane is thus tested and recorded together with the total weight of cane; then each grower is paid according to the sugar content of his cane. By means of Table XI the pounds of sugar to be paid for can be read, knowing the Baumé reading of the juice. Values are given for three different conditions of cane, whole fresh cane, whole cane that has been shocked and partly dried, and cane that has been stripped, headed, and partly dried. The table was constructed on the basis of the data given in Table XII, that is, by assuming that 2,000 pounds of each of the three grades of cane yield the indicated weight of clean cane, free from leaves and seed heads; that 60 per cent by weight of this clean cane is obtained as juice; and that the sugar content of the juice is approximately proportional to its Baumé reading. In taking this reading the cylinder that accompanies the Baumé spindle is filled to the brim with juice and the spindle allowed to settle in it, care being taken that it floats free from the sides of the cylinder, and that the surface of the juice is not covered with foam and bits of debris.

TABLE XI

FOR COMPUTING THE AMOUNT OF AVAILABLE SUGAR CONTAINED IN ONE TON OF CANE BY MEANS OF THE BAUME HYDROMETER READING OF THE JUICE

Reading on Baumé hydrometer	Whole cane, fresh	Whole cane, partly dried	Cane with leaves and seed removed
Degrees	Lbs.	Lbs.	Lbs.
8.0	90	108	128
8.3	93	112	133
8.7	97	117	139
9.0	101	121	144
9.3	104	125	149
9.7	108	131	155
10.0	112	135	160
10.3	115	139	165
10.7	120	144	171
11.0	123	148	176
11.3	126	152	181
11.7	131	158	187
12.0	134	162	192
12.3	138	166	197
12.7	142	171	203
13.0	145	175	208

The price to be paid for cane, whatever method is followed in estimating it, will naturally depend upon several factors, the guiding one of which is the relative price of other farm crops; for on this will depend the willingness of the farmers to grow cane and the price that the mill must pay them for doing so. On the basis of 1918 prices in Minnesota, both growers and manufacturers found that from $4.50 to $5.50 per ton was a fair price. On this basis 10 tons per acre yielded a good margin of profit to the grower. From the manufacturer's standpoint, these prices meant that the available sugar in the cane was paid for at the rate of 3.5 cents a pound, or the sirup obtained at 24.5 cents per gallon.

Table XII presents the various data in their relation to each other. The concentration of sugars in the juice is higher in the second and third grades of cane, owing to the partial drying of the cane, and to the leaves in the fresh cane. The seed is rated at $1 per ton of cane. and in establishing the price of the cane the presence or absence of the seed should be taken into consideration. At this price the manufacturer buys it at about one cent a pound, and after threshing and storing sells it at about a cent and a half, for feed.

The manufacturer can use Table XII for any established price per pound of sugar other than 3.5 cents. At the latter rate, fresh whole cane of *average* composition, with a juice having a density of 8.7 degrees, Baumé, and containing 12 per cent total sugar, will be valued at $3.50 for the sugar alone, or at $4.80 when the value of the seed is included. If conditions are such that a total price of $4 is equitable, the value of the sugar unit can be computed as follows:

Total price per ton	$4
Value of seed	1
Value of sugar	$3
Amount of available sugar in one ton of average cane	100 pounds
Price to be paid per pound of sugar	3 cents

This value can be applied to all three grades of cane (since they are always proportional) and to juices of all densities. In this way the grower of good cane and the grower of poor cane will each receive a price proportional to the quality of his product. This is the only practicable method of paying for cane on a rational basis; for all crops of cane are no more alike than are all loads of wheat or all cans of cream; and the above basis for payment encourages the growing of the best possible cane.

TABLE XII
COMPOSITION AND RELATIVE VALUES OF THREE GRADES OF SORGHUM CANE

	Whole plant, fresh	Whole plant, partly dried	Cane with leaves and seeds removed
Amount of clean cane per ton, lbs	1,400	1,500	2,000
Amount of juice obtained, at 60 per cent extraction, lbs.	840	900	1,200
Amount of sugar in juice, at 12, 13, and 13 per cent respectively, lbs	100	117	150
Value per ton, with sugar at 3.5 cents	$3.50	$4.09	$5.25
Value of seed at 1 cent per pound	$1.00	$1.00	.....
Total value of cane	$4.50	$5.09	$5.25

THE MARKET

In 1912 an inquiry was made among all the principal wholesalers and jobbers in Minnesota, concerning the demand for sorghum sirup. The concensus of the reports was that in most sections there is a brisk demand for sorghum sirup; that usually the amount of sirup handled by a jobber is determined not by how much he can sell, but by how much he can procure from the manufacturers; and that the present consumption of about 150,000 gallons annually could easily be increased to 500,000 gallons or more. The indications are that what was true of the sorghum sirup industry in 1912 is likewise true at present. The output of Minnesota's largest mills is sold weeks in advance of manufacture, without a word of soliciting. It is safe to say that the present consumption could be increased ten times with the aid of a little advertising and soliciting. A reduction in price of the sirup would of itself greatly increase its consumption. The retail price of the sirup at present is comparatively high. If large-scale manufacture is more widely adopted, the price to the consumer can be considerably reduced and still leave an attractive margin of profit to the manufacturer.

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